ELECTROMECHANICAL
components & systems DESIGN

SEPTEMBER 1960

THIRD ANNIVERSARY ISSUE

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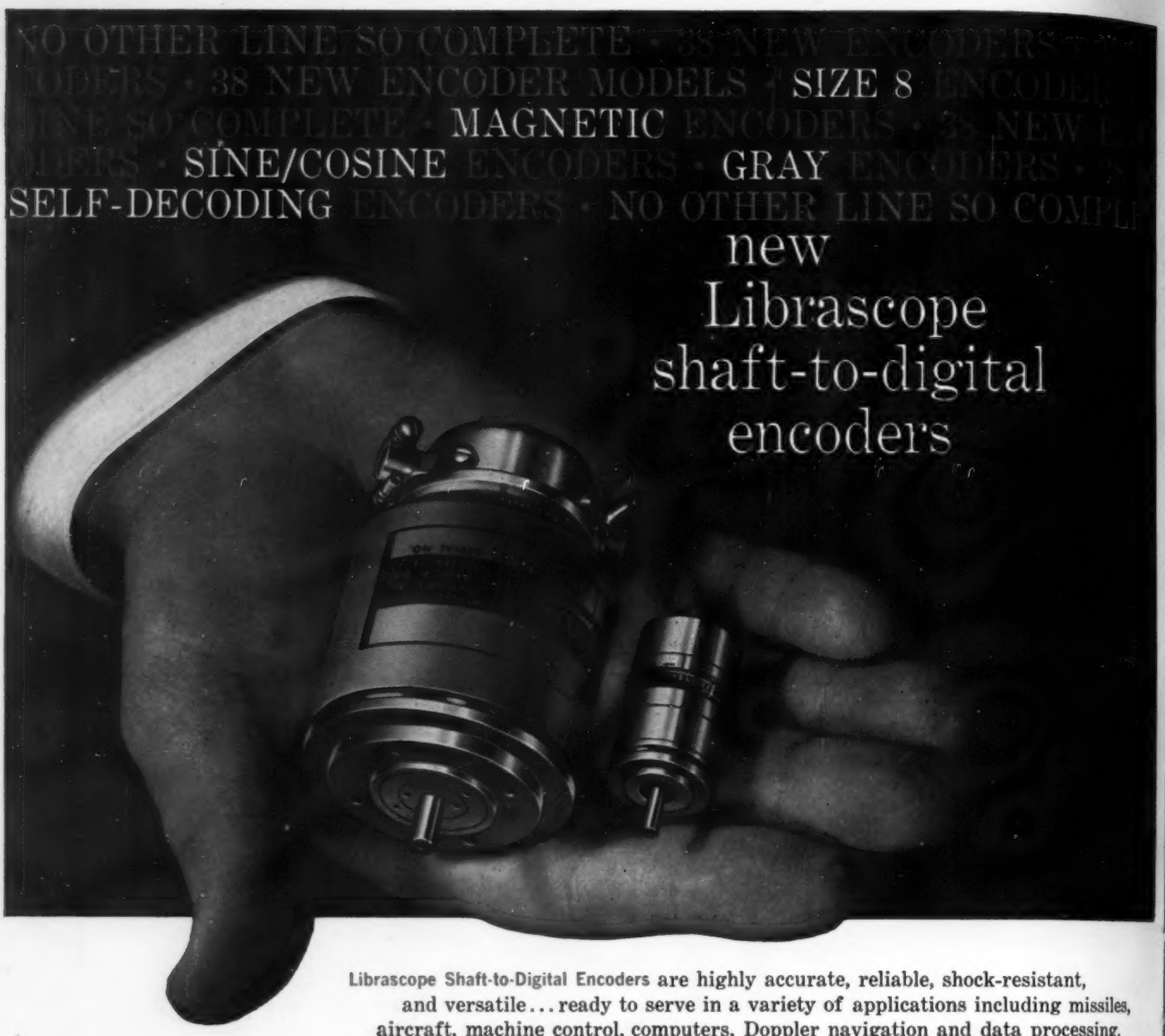
new Librascope shaft-to-digital encoders



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SPECIFICATIONS:
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Resolution: (per input shaft turn) 128 counts
Full Scale Capacity: 7 bits*
Speed: operating from 0 to 10,000 rpm
Life Expectancy: 20,000 hours at 4,000 rpm; 4×10^9 revolutions
Starting Torque: 0.1 in-oz. max.
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other popular Librascope encoders

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	0-773	oil-filled unit for increased life	
Binary	710	10 bits	1024 counts
Binary	707 (707D*)	7 bits	128 "
	713 (713D*)	13 bits	128 "
	717 (717D*)	17 bits	128 "
	719 (719D*)	19 bits	128 "
	0-713	oil-filled unit for increased life	
Self-Decoding Binary	740	10 bits	1024 counts
B/C/D	723 (723D*)	2,000 counts	200 "
	724 (724D*)	20,000 "	200 "
	733 (733D*)	3,600 "	200 "
	734 (734D*)	36,000 "	200 "
	735	360,000 "	200 "
Sine/Cosine	757-S**	4 quadrants per turn	7 bits per quadrant + limit 1
	758 758-S**	4 quadrants per turn	8 bits per quadrant + limit 1
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ELECTROMECHANICAL components & systems DESIGN

The Sourcebook of Design Ideas in Applied Electromechanics

SEPTEMBER 1960 • VOL. 4 NO. 9

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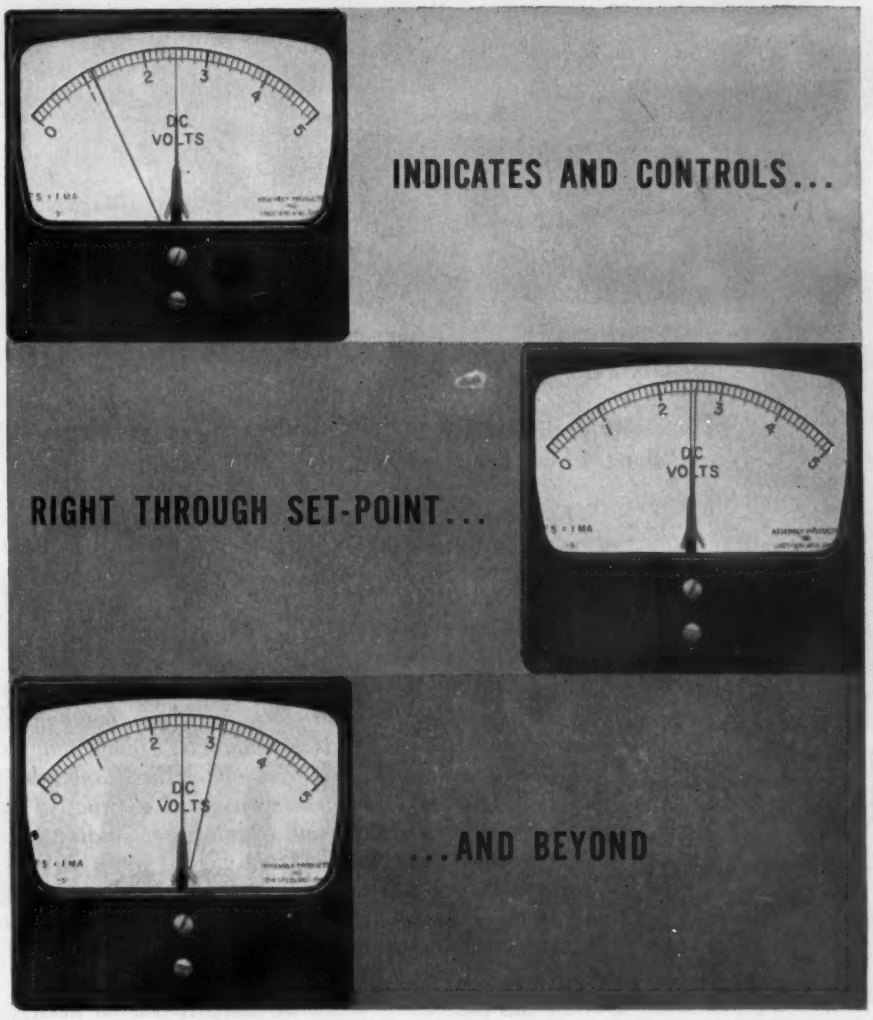
NEW—CONTINUOUS READING METER-RELAY



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Publisher's Page

GROWING UP

With this issue ELECTROMECHANICAL DESIGN starts its fourth year of publishing. In our first issue—September '57—we said:

> *"For years Industry teamed the electronic designer with the mechanical designer so they could develop together what each could not produce alone. From this merger and from company-sponsored training programs has come the electromechanical engineer—you, the designer who combines ideas and techniques from both fields into new and improved products for industry, the military and the consumer.*
>
> *"Your success is phenomenal. The merger of electronic and mechanical components and parts into unified systems, expanding by leaps and bounds, is now evident in all kinds of products. Today, few engineering problems that have been approached from either the purely electronic or the purely mechanical point of view are considered adequately surveyed. Tomorrow, no doubt, the universities will offer courses leading to a Bachelor's Degree in Electromechanical Engineering.*
>
> *"The editorial objective of this new magazine is simply to function for you as a sourcebook of ideas and techniques in electromechanical research, development, design and their management. . . ."*

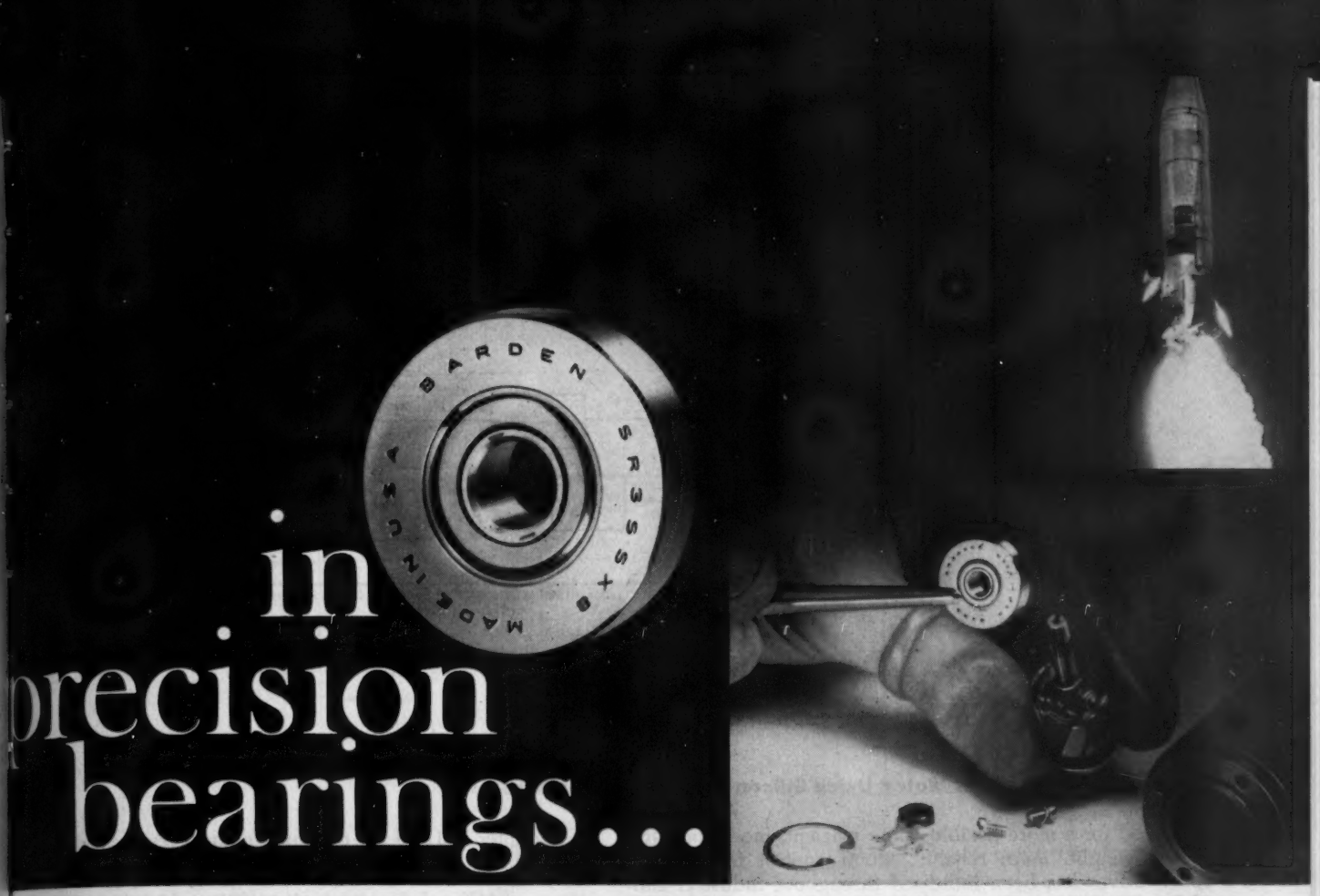
During the past three years we have found no need to change our conception of the electromechanical engineer, our editorial objectives or the name of our publication. Though we recognize that growth is usually accompanied by change, in our case the change is in breadth and scope rather than in purpose.

As far as we know, we were the first magazine that attempted to define the electromechanical engineer, indicate from whence he came and set out to service his everyday, on-the-job needs as a designer. Today, the word "electromechanical" is in greater use to describe more adequately either new components, new systems, new industries or a group of engineering functions. More and more engineers are using the word "electromechanical" in their job titles as a more adequate expression of their job functions and capabilities. More and more of the larger corporations are setting up electromechanical divisions or departments, staffed with electromechanical engineers. And while no university we know of gives a degree in electromechancal engineering as yet, more of them are considering altering their electrical and mechanical departments, either by unifying them or by contributing men from each to set up programs whereby the graduating engineer will have a greater background in mechanical and electronic theory and practice. To date, we're still pacing the universities.

We do not claim we established the profession of electromechanical engineering. We do hope that in some small way we have assisted in the recognition of you—the electromechanical engineer—as the more mature engineer, more capable of assuming direction over projects and systems utilizing electronic and mechanical concepts. And it is our continuing editorial objective to serve you to an even greater extent in the future as we grow with you.

Harold C Buchheister

Publisher



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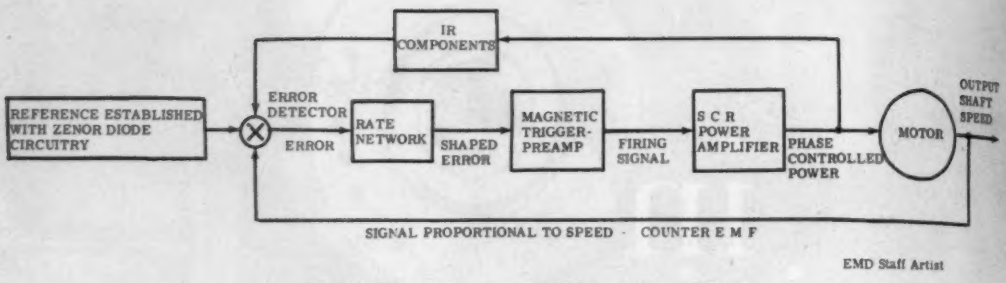


Fig. 1. Block diagram of motor controller.

VARIABLE SPEED DRIVE

Armature Control of DC Motor Using Silicon Controlled Rectifiers

The need for a more flexible, more efficient, more compact, lighter weight, more reliable, motor control for variable speed drives has been indicated throughout industry. Emphasis has been put on need for flexibility of the motor-controller combination: wide range of speed ratio, operation at very low speeds as well as full speed, soft and rapid start, acceleration control, and good regulation at high as well as low speed with varying load and line.

A control developed by ACF Electronics Div. of ACF Inds., Inc. fulfilling these requirements, is described for us by Baruch Berman, Chief Engineer at ACF's Commercial Products Devl. Dept. The controller described is used with a dc shunt motor, however, with slight modification, it may be used with other types of motors, such as series, universal, and servo motors. Figure 1 is a block diagram of the system.

ERROR DETECTOR

The error detector compares the motor speed with a preset speed to provide an error control signal to the trigger-preamplifier.

Counter EMF of the dc shunt motor is represented by the equation

$$EMF = [\,(n \times z \times \Phi\,)\,/60] \times 10^{-8}\ (\text{volts})$$

where Z is the total number of active conductors per path and is a constant once the machine design has been established.

Φ is the air gap flux cut by the armature conductors.

N is revolutions per minute of the armature.

The applied voltage E_g has to be large enough to overcome both EMF and armature resistance.

$$E_g = EMF + IRa$$

where I is the motor armature current

Ra is the motor armature resistance

The motor speed equation is

$$N = 60\,[(E_g - IRa)/Z\Phi]\ 10^8$$

This equation shows that if flux Φ is held constant and if IR is low, the counter EMF is proportional to motor speed.

The detector makes use of this relationship by using the

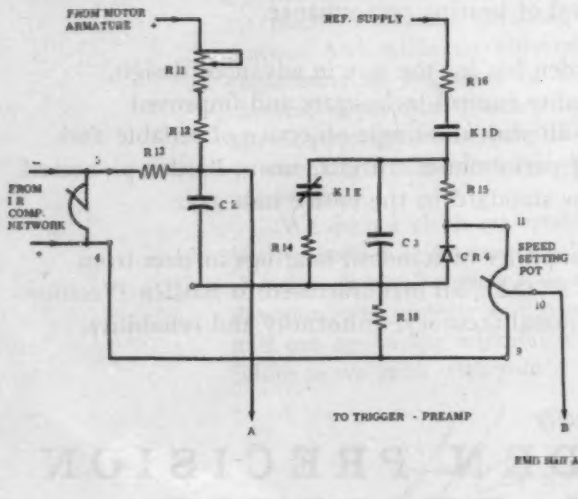


Fig. 2. Detector circuit.

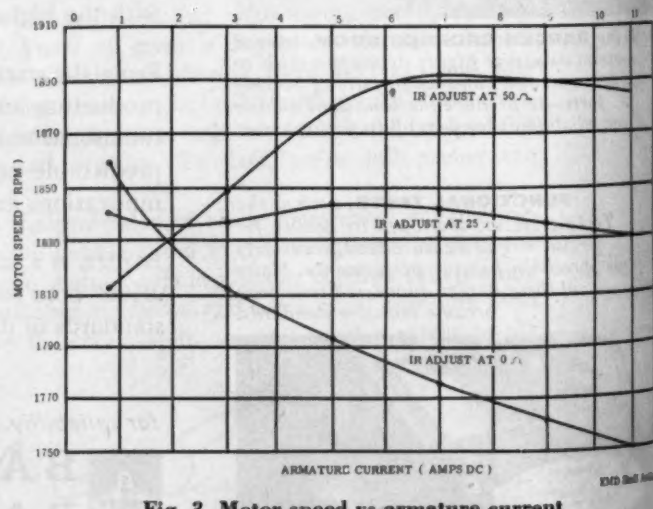


Fig. 3. Motor speed vs armature current for three IR adjustments.

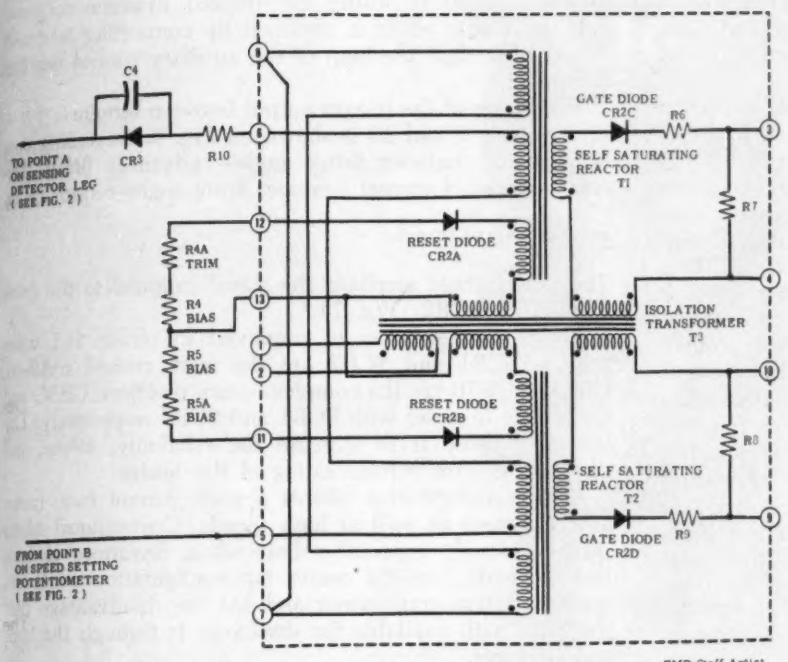


Fig. 4. Magnetic trigger-preamplifier circuit.

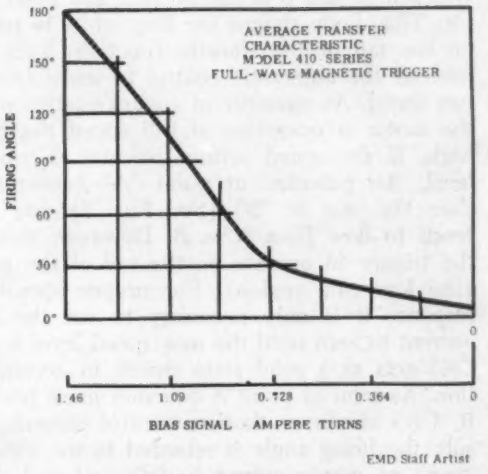


Fig. 5. Transfer function of the firing angle vs bias setting of the trigger-preamplifier.

counter EMF from the motor armature to sense motor speed. To compensate for the slight error due to the IR drop another network (described later) is provided. The speed regulation obtained with this method of sensing and with IR compensation is ±25 rpm at any speed and with load varying from zero to full.

For higher accuracies a tachometer is mounted on the load shaft which supplies an independent signal to the detector.

Fig. 3 shows speed regulation with different settings of the compensating rheostat R3. A regulation band of 15 rpm (better than ±0.5%) is obtained.

Power for the reference leg, comprising resistors R 16 and R 15 and Zener diode CR4, is obtained from the ac line in half-wave form. Resistor R18 and capacitor C3 accomplish two functions: they filter out the half ripple, which may amount to 120% without filtering, and delay establishment of the reference. The reason for the latter is to provide smooth, controlled acceleration and to allow starting and running up to any preset speed under different conditions of load.

A safety feature is obtained by supplying the field of the motor in the same fashion as the reference and connecting them to the same points. With loss of field power the reference supply is also lost and the controller is forced to cut-off so that no power is supplied to the motor, thus preventing a speed run away under no load or a motor burnout under full load.

The sensing leg, comprising resistors R11, R12, R13, rate capacitor C2 and common resistor R18, acts as a voltage divider to provide a portion of the armature voltage for sampling against the voltage set by the speed setting potentiometer.

The speed setting pot obtains its potential from the Zener diode CR4. Best voltage stability of CR4 is obtained by insertion of R15, because the higher the ratio of the series resistance with respect to the dynamic impedance of CR4, the better the diode regulation, provided the impedance of R17 is properly matched.

The error signal across points A & B of Fig. 2 is applied to control terminals 5 and 6 of the trigger preamplifier.

TRIGGER — PREAMPLIFIER

The magnetic trigger-preamplifier, Fig. 4, delivers a signal to the gates of the power stage whose phase is proportional to the error signal supplied by the detector.

When no signal is applied to terminals 5 and 6, the preamp delivers minimum output—the firing angle of the output is retarded. Linear operation at low speed is obtained by biasing. The classic problem with controlled rectifiers or magnetic amplifiers has always been operation in the zone close to minimum output. In this zone they become very sensitive to gate or grid characteristic and tend to operate asymmetrically. Very close matching sometime alleviates this situation. However, close matching is costly and causes replacement problems. Bottom speed operation in ACF's design is set with bias resistors. Each reactor is

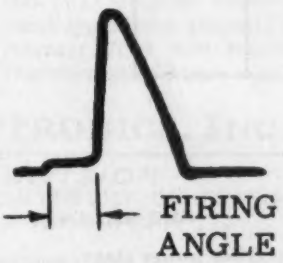


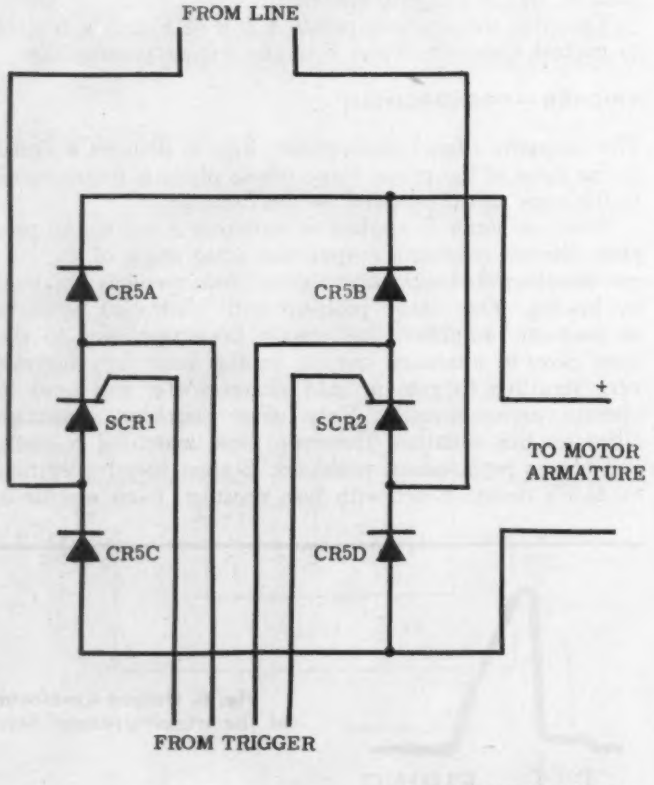
Fig. 6. Output waveform of the trigger-preamplifier.

provided with its own resistors. This technique is made possible by use of reset bias rather than MMF bias.

Trim resistors R4A & R5A allow balancing of the trigger output phase angle independently at the most critical position of the curve—near cutoff. Fig. 5 is a transfer curve of the firing angle vs bias seting.

A nonlinear component, CR3, shunted by rate capacitor C4 and in series with R10 is placed in the control loop between terminals 6 of the preamp and point A of the detector. This diode shapes the loop so as to prevent operation on the tail of the transfer function. Such operation may mislead the automatic control to see a false value of output speed. An example of such a condition follows: When the motor is operating at full speed the counter EMF is high. If the speed setting rheostat is turned to a lower level, the potential at point "A" becomes more positive than the one at "B" (See Fig. 2) and control current tends to flow from A to B. However, this polarity forces the trigger to operate on the tail of the transfer function (the low gain region). For proper operation and fastest response it is only necessary to cut the flow of control current to zero until the new speed level is reached. Diode CR3 acts as a solid state switch to accomplish this function. As soon as point A becomes more positive than point B, CR3 blocks so that no control current flows. As a result, the firing angle is retarded to the vicinity of 170 degrees, no power output is delivered and the motor slows down quickly to the desired level.

This feature is especially important in the application being described because of the long mechanical time constant of the motor. Inertia of the motor tends to maintain the existing speed level, thus tending to sustain the existing counter EMF and prevent the desired control.



EMD Staff Artist

Fig. 7. Silicon controlled rectifier power stage.

The rate network consisting of C4 and R10 further improves control by delivering just enough breaking signal to the preamp to insure the desired dynamic response. Additional rate effect is obtained by connecting terminals 7 and 8 to close the loop of the auxiliary control winding on itself.

Waveform of the trigger output between terminals 3 & 4, or terminals 9 and 10 is shown on Fig. 6. Increasing control current reduces firing angle— advances firing. Decreasing control current increases firing angle—retards firing.

POWER AMPLIFIER

The power stage amplifies the signal supplied to the gates of SCR1 & SCR2 (Fig. 7).

Bridge configuration is employed to obtain full wave output. SCR1 and SCR2 are the main control rectifiers. CR5A & CR5B are the complementary rectifiers. CR5C and CR5D are in series with SCR1 and SCR2 respectively. The latters' purpose is to increase the reliability, safety, and range of inverse voltage rating of the bridge.

Bridge configuration affords a good current form factor at low speeds as well as high speeds. Conventional motor control circuits, expecially those using thyratrons as control elements, use the center tap configuration which requires a heavy transformer and has the disadvantage that the only path available for discharge is through the control elements.

TABLE I

Speed:	1900 rpm			700 rpm	
R.M.S. Current	D.C. Current	Form Factor	R.M.S. Current	D.C. Current	Form Factor
13.88	11	1.26	13.42	11	1.22
11.90	9	1.32	11.45	9	1.27
9.68	7	1.38	9.37	7	1.34
7.37	5	1.47	7.20	5	1.44
4.80	3	1.60	4.80	3	1.60
1.80	1	1.80	2.00	1	2.00

Table I presents motor armature form factors at two discrete speeds calculated from test data.

The data show that the form factor is better at the lower speed. Better form factor, which mean less losses and heating is an advantage at lower speeds where cooling

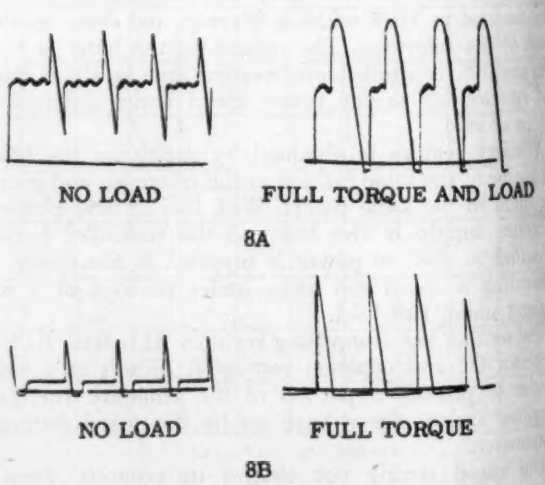
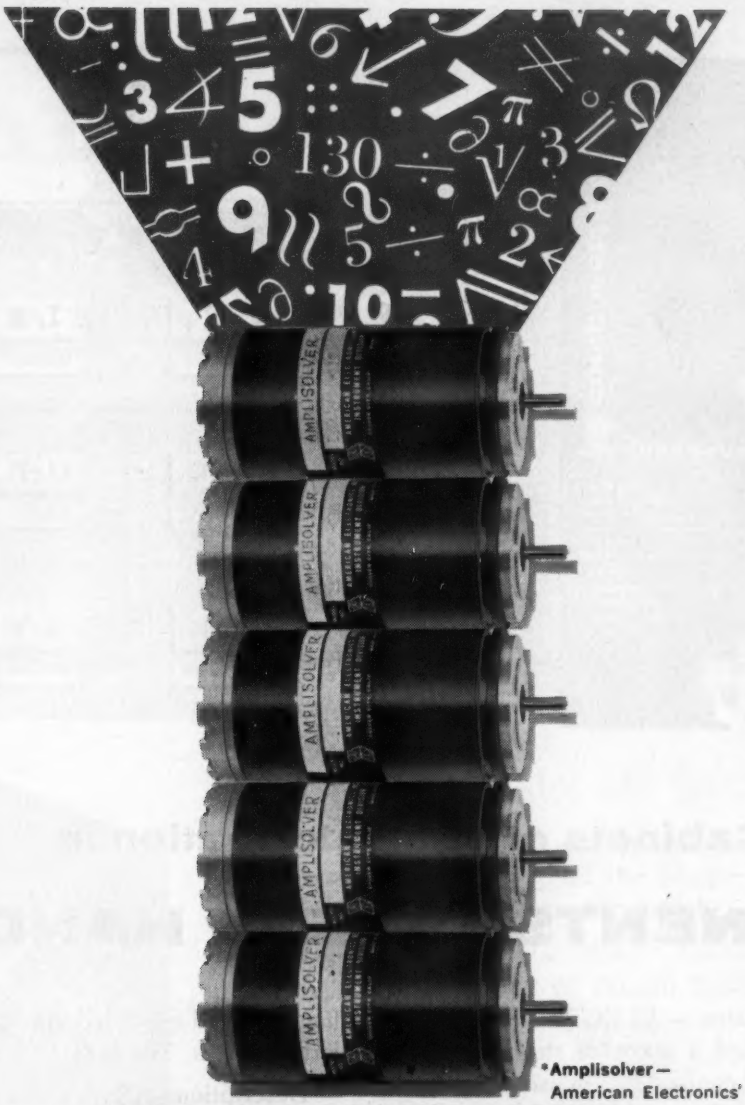


Fig. 8. Oscillograms of motor armature voltage.



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Primary: Stator. **Input:** 10 volts. **Test:** 10 volts. **Frequency:** 400 cps. Z_{RO} **Rotor Impedance (ohms):** Stator open circuited, 54K tuned. Z_{SO} **Stator Impedance (ohms):** Rotor open circuited, 90K tuned. **Total Null Vltg.:** .015. **Max. Error:** .1%. **Transformation Ratio:** .600 ± .001 R/S. **Phase Shift:** 0 ± .1°.

AMPLISOLVER—MODEL 15RA55E-11D

Primary: Stator. **Input:** 10 volts. **Test:** 10 volts. **Frequency:** 400 cps. **Amplifier Power Supply:** 28 ± 1 volt, regulated. **Input Impedance (ohms):** 100K min. Z_{RO} **Output Impedance (ohms):** 270 + j400. **Total Null Vltg.:** .015. **Max. Error:** .05%. **Transformation Ratio:** 1.000 ± .001 R/S. **Phase Shift:** 0 ±.1°.

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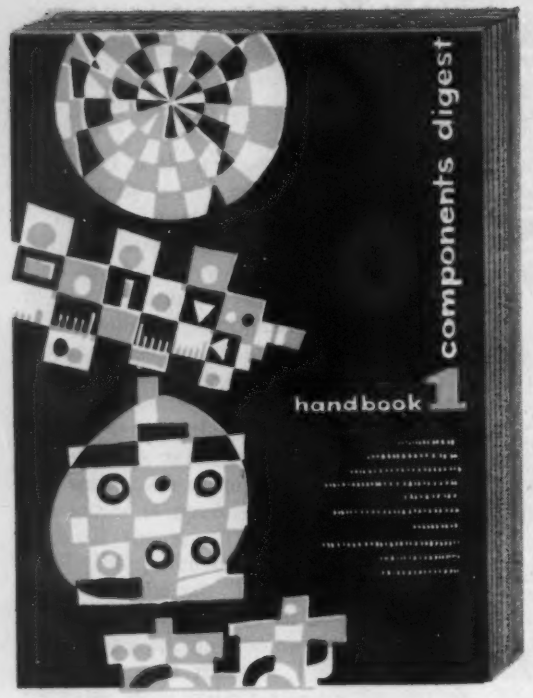

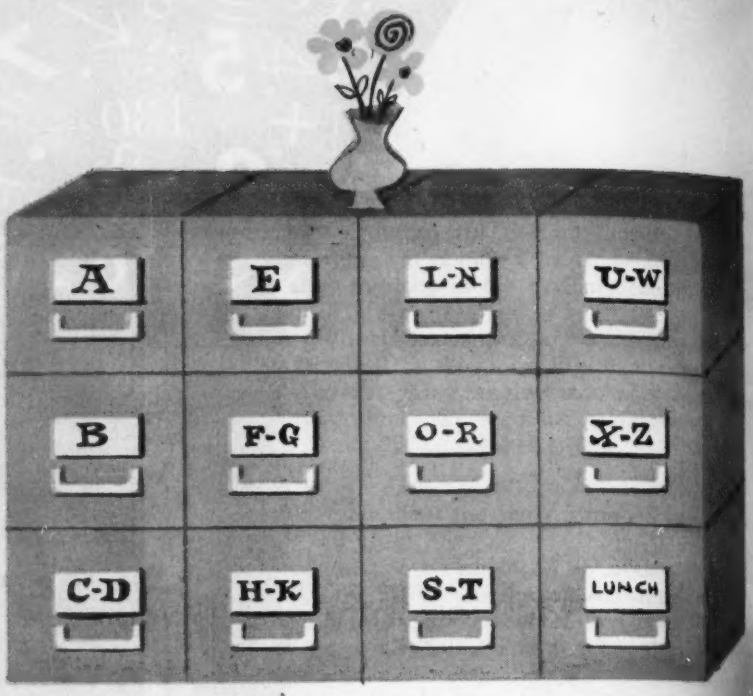

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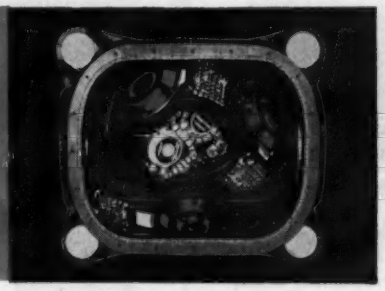

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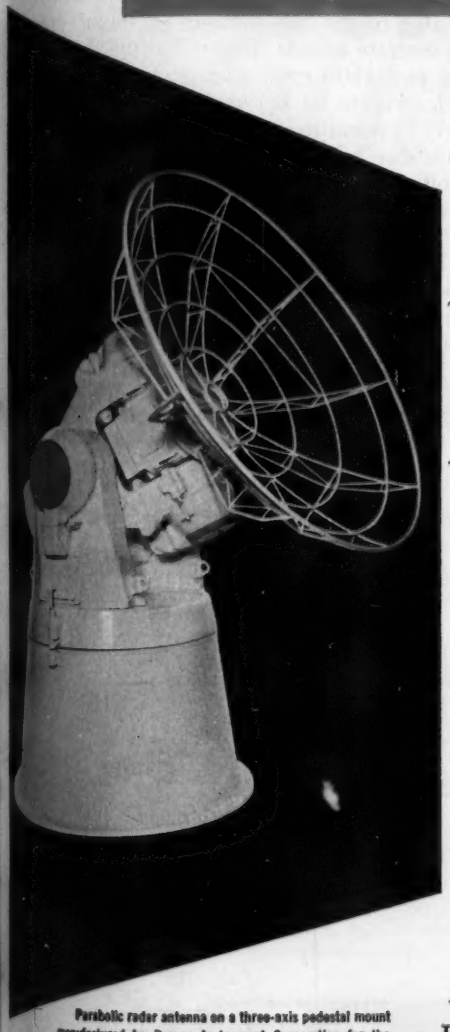

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T-1321	20 oz.-in.	57	1.94	.50
T-2136	35 oz.-in.	42	2.81	.63
T-2108	60 oz.-in.	32	2.81	1.00
T-2907	.85 lb.-ft.	79	3.73	1.09
T-4006	1.8 lb.-ft.	100	5.13	1.25
T-5106	2.7 lb.-ft.	86	6.25	1.31
T-5703	7.0 lb.-ft.	246	7.20	1.63
T-720	11.0 lb.-ft.	327	9.00	1.63
T-8001	25 lb.-ft.	925	10.50	2.63
T-10001	35 lb.-ft.	620	13.69	4.30
T-10004	100 lb.-ft.	1020	12.75	5.75
T-18002	300 lb.-ft.	1300	26.63	5.82
T-18004	900 lb.-ft.	4330	26.50	10.56
T-36001	3000 lb.-ft.	7400	45.0	10.25

For complete data on these or other Inland d-c pancake torquers, address Dept. EL, Inland Motor Corporation of Virginia, Northampton, Massachusetts.

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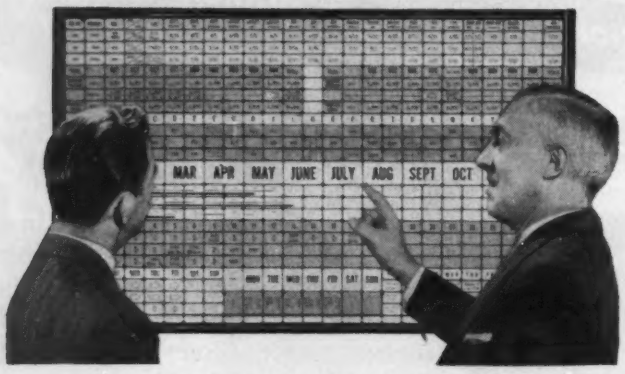

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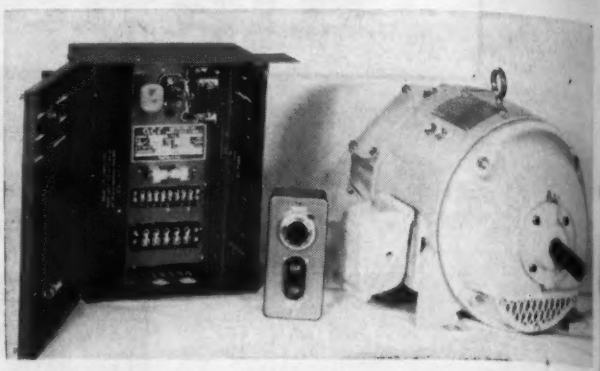

Fig. 9. Photograph of ACF Industries' SCR Variable Speed Drive.

effects are not as good. Form factor also improves with load. However, at no load where its value is maximum (2.0) heating is low because input current is low.

Figures 8a and b are oscillograms of motor armature voltage at two discrete speeds. Figure 8a top shows operation at no load and 1800 rpm. The power is switched on late in the cycle. Figure 8a bottom shows full load operation with power transmitted over a large portion of the cycle. The kick due to armature inductance is very apparent. The voltage reverses, but very slightly, as it gets clamped by the bridge.

Figure 8b shows oscillograms of motor armature voltage at 250 rpm. The full torque current developed with a low firing angle indicates the wide range of operation of the control. Stable operation is maintained throughout.

Typical input and output power for the controller described are

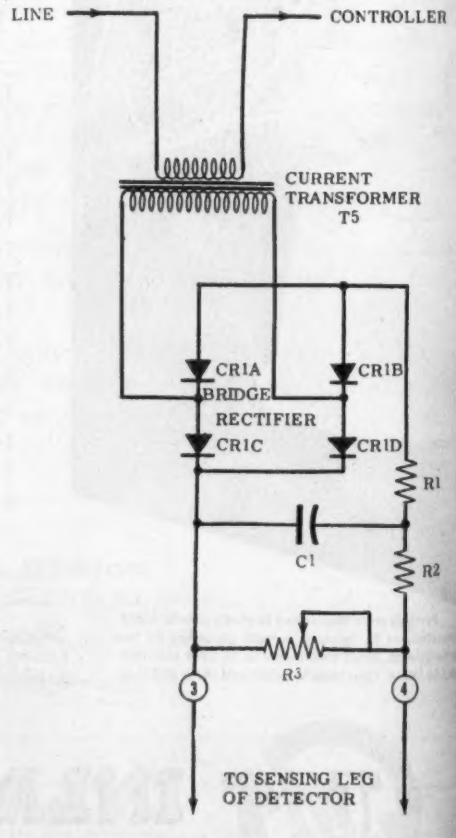

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Fig. 10. IR compensating network.

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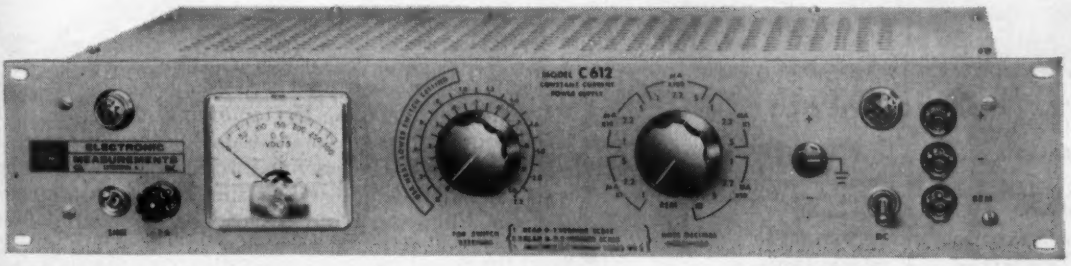

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MODEL	OUTPUT	VOLTAGE COMPLIANCE (MINIMUM)	DIMENSIONS			PRICE
			H	W	D	
C612A	1 uA to 100 ma	100 V	3½	19	9¼	$289
C624A	2.2 uA to 220 ma	100 V	3½	19	9¼	$364
C621A	5 uA to 500 ma	100 V	5¼	19	15	$479
C620A	5 uA to 500 ma	50 V	5¼	19	15	$449

*Load regulation is 0.1% for all models except 0.2% on 1 and 2.2 uA ranges of Models C612A and C624A.

You'll find the programming feature, voltage compliance, and other performance data fully detailed in four-page Specification Sheet 3072A. Ask your local E/M representative or write . . .

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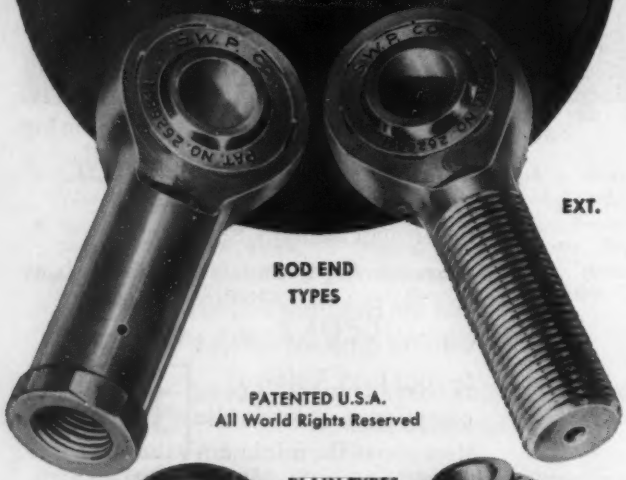

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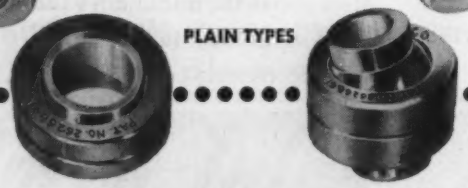

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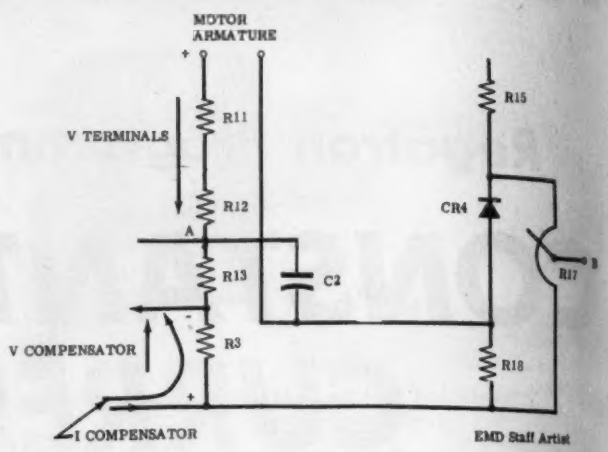

Fig. 11. Circuit connections between the IR compensation network and the detector.

INPUT		OUTPUT
(watts)	(VA)	(DC watts)
2040	2840	1900

$$\text{efficiency is } \frac{1900}{2040} \times 100 = 93\%$$

This overall efficiency, is much better than any obtained with thyratron magnetic amplifiers and other existing controls.

Figure 9 shows the controller in a drip proof enclosure designed for wall mounting.

IR COMPENSATING NETWORK

The IR compensating network (Fig. 10) improves the speed regulation by modifying the error in the detector control loop to compensate for the difference between the counter EMF generated in the motor and the terminal voltage supplied to the sensing leg of the detector.

When the motor is loaded, the control fires the silicon controlled rectifiers earlier in the cycle allowing a higher current to flow in order to develop the torque required to sustain the set rpm. This current flows through transformer T5 primary and is stepped down to the level and impedance desired by the secondary turns. The secondary current is rectified by the bridge rectifier CR1 and filtered by the network R1, C1. Filtering is mandatory in this case since the armature current is a controlled sine of the form shown in Figs. 8a & 8b exhibiting high peaks and valleys. Filtering smooths out the wave so that the divider obtains an essentially dc voltage. This dc voltage is proportional to the ac input current to the controller.

Terminals 3and 4 of the compensator are connected into the detector network as shown in Fig. 11. The compensator voltage, V compensator, bucks the sensed voltage, V terminals. With rising compensator voltage, V terminal at point A becomes less positive with respect to the armature negative point, thus it also becomes more negative with respect to point B. As a result, more control current flows than would if the signal of the compensator were not present, the Firing angle is advanced and motor speeds up to furnish a terminal voltage that represents the true generated EMF.

The IR rheostat R3 is adjustable to allow setting the compensation to the desired level. Fig. 3 shows that very good regulation is obtained when the rheostat is set to 25 ohm.

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0-36*	0-20	CR-36-20	105-125	55-65	3 P-P	±0.01 % or ± 1 mv	±0.02% or ± 1 mv	7 x 19 x 16⅝	70	845
0-18**	0-30	CR-18-30	105-125	55-65	3 P-P	±0.01 % or ± 1 mv	±0.02% or ± 1 mv	7 x 19 x 16⅝	70	845

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ELAPSED TIME PROGRAMMER

Three Design Approaches for Controlling Closing of Contacts by the Joint Positions of Timing Drums

Often, in going from the design of a prototype model to the development of a production unit, the designer is obliged to make expensive refinements. In some cases, a more economical procedure would be to take an entirely new functional approach to the prototype design.

Mr. Ed Hildum, Chief Engineer, Calculagraph Co., Harrison, N.J. gives us an excellent illustration of this approach in his design of a program device for an elapsed time computer.

Mr. Hildum's basic problem was to control the closing of a contact by the joint positions of two drums. If one drum has 60 divisions and turns at one rpm and the other drum has 24 divisions and turns at one revolution per day, the two together can identify any one minute of the 1440 in a day.

MECHANICAL DESIGN

The first solution to the problem, shown in Fig. 1, was the result of a mechanical engineering approach. Brass timing drums with break out segments on the rims were used. A reading lever with two fingers, one for each drum, was cammed up to allow the drums to move. Movement of the lever was down and if the two fingers of the lever dropped into the breakout segments of the drums, the lever would move down completely, thus setting in motion one of three bails which control the contacts.

From the results of the construction and testing of this model, Mr. Hildum found the following disadvantages:

- Parts were expensive and heavy.
- Construction of the breakout segments on the drums and the fingers on the levers was difficult.
- Change in program required replacing of broken segments with spring clips.
- Minute drum shaft depended on spring advance.
- Many springs resulted in heavy torque on drive motor.

Mr. Hildum revealed that this unit operated the bell system in the plant for four weeks before failure, caused by stalling of the motor.

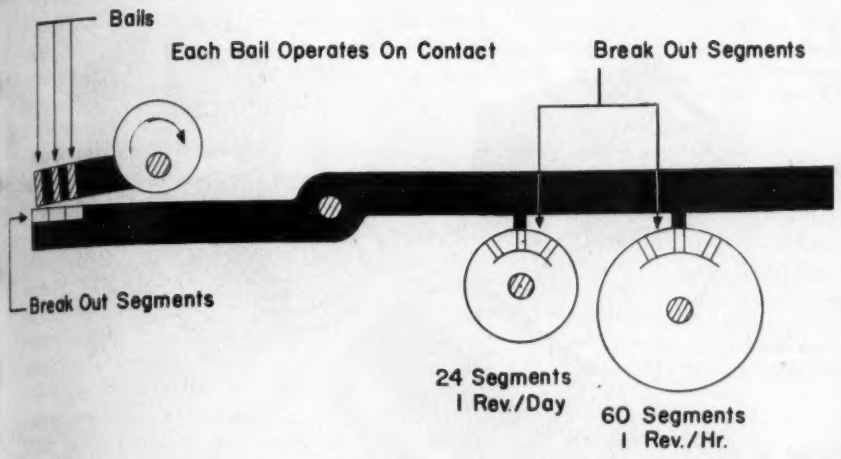


Fig. 1 Cam raises lever once per min. for intermittent advance of timing drums. Twelve such configurations were required for the complete program device.

ELECTRICAL DESIGN

Fig. 2 illustrates the second design which was primarily electrical. Sixty radial slots were made in a drum which was next to a circular slip ring. A split contact wiper rode around the inside of the drum with one finger against the slip ring and one ready to contact any lug pushed in through a radial slot.

One drum with 24 radial slots was placed at the end of stacks of 60-minute drums and the slip rings of the 60-minute drums were wired to lugs that were pushed into the 24-hour drum at the desired position. The drive had a positive advance but was returned by a spring. Tests showed the following advantages over the previous design:

- No breakout segments needed to set up program.
- Smaller unit.
- Much less drive power required.

The tests also showed the following disadvantages:

- Limited flexibility due to single 24 hour drum.
- Wires to lugs resulted in mass of tangled leads and made changing program difficult.
- Assembly of contact springs inside drum was impractical for production.

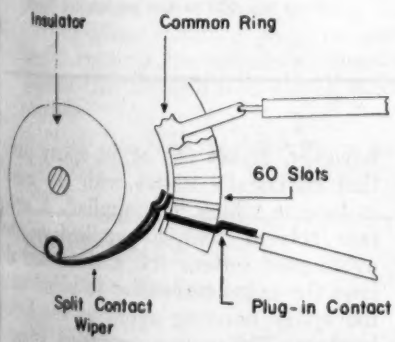


Fig. 2 Split contact wiper advances intermittently once each minute and shorts the plug-in contact to the common ring at the proper minute. 60 division drums are used in series with a similar drum with 24 divisions.

ELECTROMECHANICAL DESIGN

Mr. Hildum's final design, shown in Fig. 3, was both electrical and me-

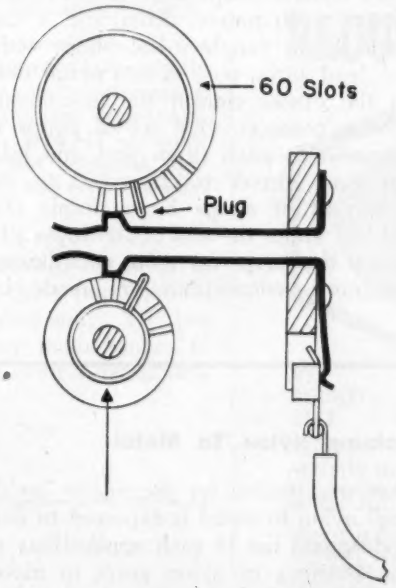
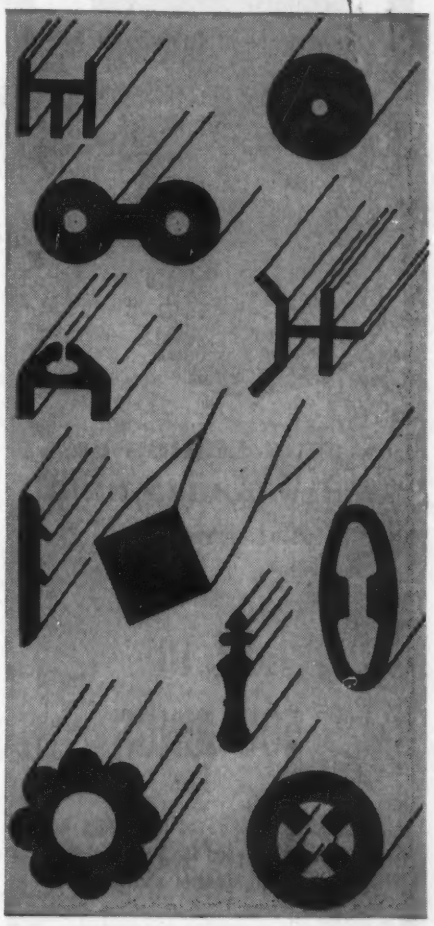


Fig. 3 Drums are advanced intermittently, the upper one, once a minute and the lower one, once an hour. Each plug lifts its contact strap on each revolution but the contacts close only when both plugs lift the straps at the same time. Twelve of these units make up the complete program device.

ACE PLASTIC EXTRUSIONS



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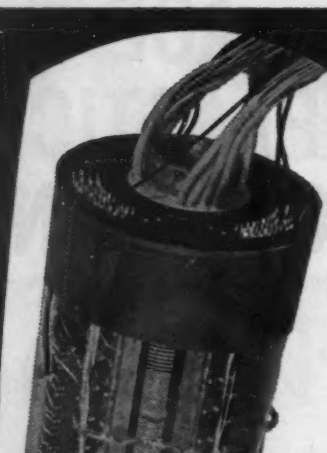

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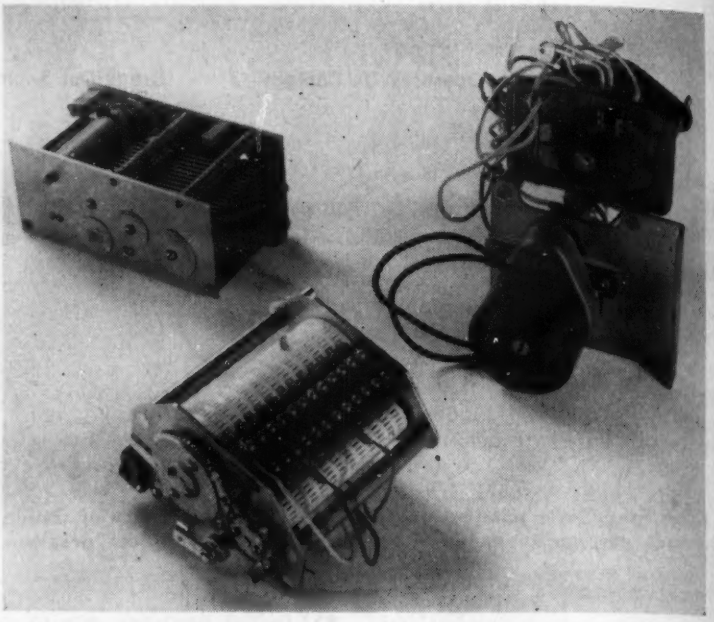

Fig. 4 The three designs of the program device. Extreme left: first design depended on cam to raise levers; extreme right: second design, primarily electrical, depended on contact lugs pushed through radial slots; center: final design used simple metal plugs for actuation of program. The finally adopted program device is incorporated into a time computing machine, called the Calculagraph, which provides timing impulses for the recording of elapsed time for production operations, labor distribution or other control purposes.

chanical and eliminated the problems encountered in the first two designs. Two contact straps were mounted between a 60-minute drum and a 24-hour drum. Simple metal plugs, without lead wires, pushed into radial slots in the drums control the movements of the contacts. One set of straps is common to each drum and one lead for each circuit is connected to the other set of straps by a simple clip pushed under the end of the straps. To group the straps for more complicated programs, connections are made by additional clips without leads.

Advantages of the final model were:

- Little power required for drive.
- Lighter parts used in unit.
- Plugs easily moved to change program.
- Simple wiring.
- Positive drive.
- Snap switch to take or make or break arcs.
- Flexible programming.

Fig. 4 shows the three complete designs.

Write No. 222 in Box on Inquiry Card

Joining Nylon To Metal

Two-step process for chemically "welding" nylon to metal is expected to find widespread use in such applications as the bonding of nylon gears to metal shafts or the securing of threaded screws or rods in nylon-and-metal assemblies. In such applications in the past, the self-lubricating qualities of molded nylon have generally required a mechanical interlock arrangement to prevent slippage between the nylon and the metal. The joining method, however, makes use of an epoxy p... that chemically unites with the ... surface to which it is applied. A ... rate solvent solution applied to ... nylon part softens the surface and ... lows the nylon molecules to blend ... the epoxy bonding agent as the ... hardens. The entire operation is ... formed at room temperature, achie... an extremely tough, shock-resis... union between the nylon and the ... within a few hours. Plastic Associ... Laguna Beach, Calif.

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ELECTRICAL CONNECTORS

Self-aligning Contact Pins Can Be Inserted at Any Angle

Basic design of self-aligning connectors, developed by Cole Electric Co., Culver City, Calif., is a universal joint employing a two-ball and split-sleeve socket. The ball end of each contact pin mates with the split-sleeve socket that is loosely retained with one of the balls, forming a receptacle unit. Two garter springs expand or contract the sleeve to allow easy entrance or withdrawal of the mating ball pin regardless of the alignment of the pin or connector, yet insuring positive, optimum electrical contact.

Due to the two-ball and socket principle, contact can always be made easily even though pins may have become misaligned due to rough treatment, high shock, vibration or extreme temperature changes. Design permits angular insertion or extraction without damaging the pins or increasing pressures.

Pressures required to open or close the connector are extremely low. For example, a 48 contact connector using #16 pins requires an insertion force of 18 lbs. and an extraction force of 15 lbs.

Because the self-aligning pins can be inserted at an angle, low-cost quick action hinge-type connectors can be used in place of more expensive screw-on, screw-jack or power-lever types. When the hinge principle is used, insertion and extraction forces are reduced further due to the leverage action.

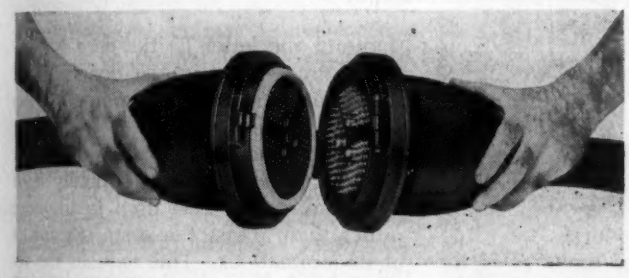

Fig. 1 Cole Electric Co.'s self-aligning connector used for quickly connecting or disconnecting the Convair Atlas missile with ground service equipment. Depending on requirements, Cole connector fittings can be made of stainless, aluminum, phenolics, dialphalate, fiberglass, nylon, ceramic or other materials. Because close tolerances are not required, special design prototypes can be made quickly and economically.

Various types of fast-acting latches and toggle locks can be designed for instantaneous disconnecting. In order to provide sequence switching, long and short pins can be used in either standard plugs or dead-front units. The pin length controls the sequence. Sleeves are made longer to provide the required over-travel, making control monitoring possible.

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WORTH FILING

Production Machinery

46 page catalog describes automation components and entire assembly machines. Automatic Geneva motion index tables, dial assembly presses, rivet spinners and pecial asembly machine, along with tooling and automatic feeds are listed.

Source: Precision Detroit Co.
Detroit, Michigan
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Vibration Test Systems

14 page bulletin describes shakers, power supplies, controls and accessories of vibration test systems rated from 1250 to 2500 pounds generated force and developing up to 100 g. Four systems range in force from 1350 lbs. to 2500 lbs. depending on the choice of amplifier. For any chosen force, variations of controls and accessories are available.

Source: Unholtz-Dickie Corp.
Hamden, Conn.
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Electrically Operated Valves

20 page bulletin describes 2, 3 and four-way electrically operated valves. Included are specifications, outstanding characteristics, flow charts, optional features, ordering data and dimensions.

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Decade Counter Tubes

12 page handbook describes the construction, operating principles and applications of decade counter tubes used in computers and tabulating machines, radiation measuring instruments, frequency dividers and other electronic equipment. New drive circuits for medium and high speed types are included (100 kc).

Source: Sylvania Electric Products, Inc.
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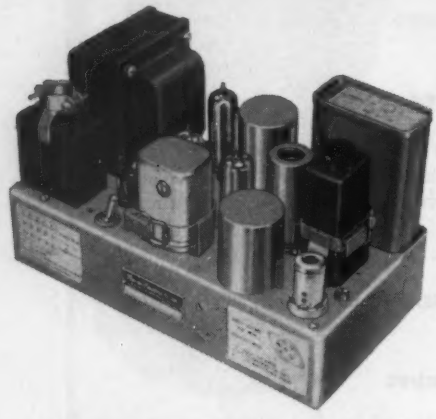

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ELECTRICAL TRANSFORMER

Nested Laminations As Cores Offer Greater Design Flexibility

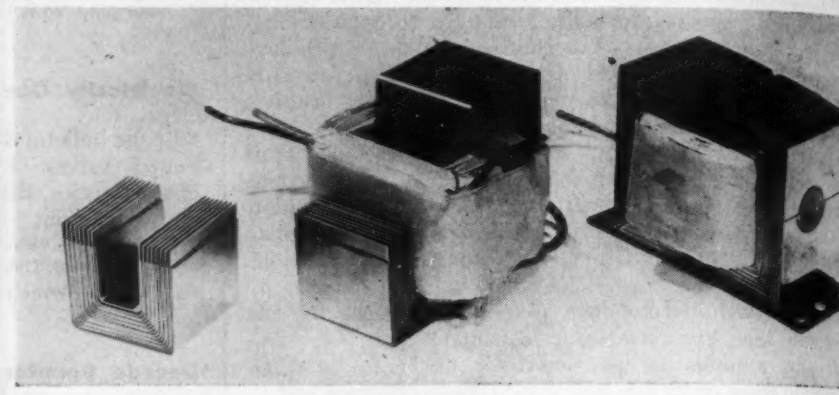

Fig. 1 Assembly of Sylvania Electric's Flexi-core transformer. On the left is one of the four nests of squared "U" shape laminations that are used to complete the transformer. In the center, the transformer's coil and leads have been added. On the right, the transformer has been completed with the addition of the nested laminations which have been secured by welds. Flexicore transformer with 1.6 core/coil weight ratio has identical performance with respect to power output, efficiency, etc., with 12½% weight saving and 9½% size saving as compared to an EI transformer having a core/coil weight ratio of 3.

Described as a fundamental new concept in transformer design, an electrical transformer, called Flexi-core, is smaller and lighter than conventional types with identical operating characteristics.

According to Mr. O. Howard Biggs, Div. V.P. of Research & Engineering, Sylvania Electric Products, Inc., Ipswich, Mass., the shape and size of the new transformer core can be designed to fit a specific need within broad limits. Thus, by making it possible to select a transformer for the job, rather than having to accept and adapt a transformer, engineers will have more design freedom.

DESIGN DETAILS

In explaining the Flexi-core concept, Mr. Biggs revealed that the heart of the new transformer is a formed core that consists of nest of laminations, or layers, of fabricated steel strips from a continuous roll. Each of these cores consists of two "U"-shaped nests of strips; two nests are fitted together, with the strips at the top of the "U's" interleaved, or meshed. The resulting unit is a hollow rectangle, square, or other shape. A so-called "core" type of transformer utilizes one of these hollow units; in a shell-type transformer, two of these units are placed together so that a center post is formed. (The core of the conventional, more complex EI transformer consists of laminations of metal stamped in the shape of the letter E; the core is completed by closing in the open side of the E with a metal strip stamped in the form of the letter I.)

Nested cores allow the magnetic lines of force to flow continually with the grain of the steel used in the core rather than across the grain, as occurs in EI laminations. This reduces the resistance of the magnetic circuit, and therefore permits the Flexi-core to operate as efficiently as a conventional transformer that has a larger and heavier core.

Pointing out that for the past few years engineers have been using electronic computers to "design" transformers, Mr. Biggs claimed that computer results could not be followed exactly because of the limitations imposed by EI laminations. Now, he added, the Flexi-core concept permits 100% application of computer results to design and production.

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Handy reactance slide rule is available for simple calculation of resonant frequency, capactive reactance, and inductive reactance. The slide rule also solves coil "Q" and dissipation factor problems that cover a frequency range from 5 cycles per second to 10,000 megacycles. Price $1.00

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Vibration Exciter

Said to be approximately one-half the size of a comparable air-cooled unit, an oil-cooled, 2500-pound vector force vibration exciter, was designed for both sine wave and random motion testing. According to the manufacturer, the oil cooling system and the magnetic circuit that provides increased flux density make the unit the most efficient 2500-pound vector force exciter now available. Acceleration capability is in excess of 100g and the frequency range is 5 to 5000 cps. Uni-mode suspension permits one-inch double amplitude travel for continuous duty and linear table motion. The unit can be used in environmental test chambers with temperatures from −100 to 300 F., altitudes to 250,000 feet and relative humidities of 0 to 100%. MB Electronics, New Haven, Conn.

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Medium and high power transistors can be tested under variable duty cycle conditions with a direct reading instrument. The test set employs a pulse drive technique to make direct measurements of dc parameters at power levels equal to the maximum dissipation of the transistor. Both the ammeter and voltmeter detect peak current pulses producing a measure value equivalent to a steady dc current. Readings are registered on 3″ meters. Power transistor dc current gain, saturation, measurements; input and output impedance, leakage current and breakdown voltage can be tested as well as diode leakage and breakdown measurements. Baird-Atomic, Inc., Cambridge, Mass.

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Flux Meter

Nuclear fluxmeter provides precise measurement and/or control of uniform magnetic fields in laboratory and industrial magnet applications. Instrument range is 1 to 52 kilogauss. The unit functions without local oscillator near the magnetic field thus eliminating air gap clutter. Probe is completely buffered from frequency thus, frequency instabilities caused by varying external components or probe position are eliminated. As a control device, the instrument, with a crystal frequency control accessory, holds fields stable against residual slow drift or external stray magnetic interferences not sensed by straight current regulation. Varian Associates, Palo Alto, Calif.

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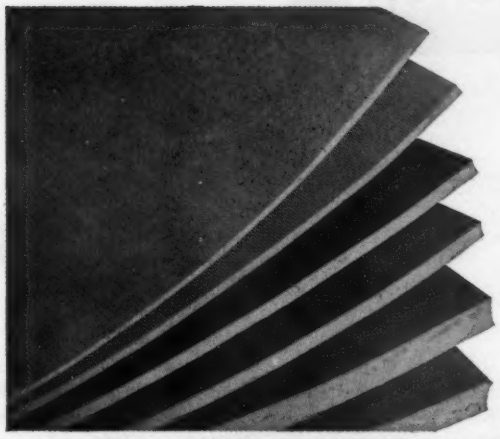

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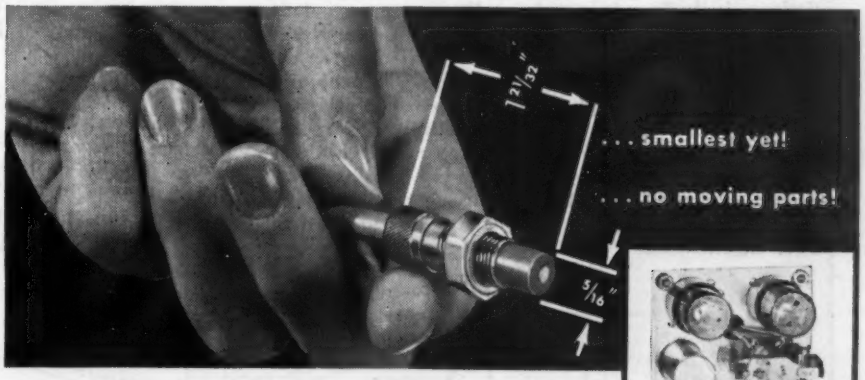

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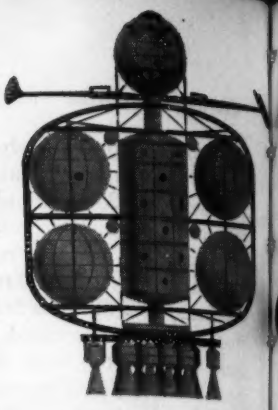

SPACE

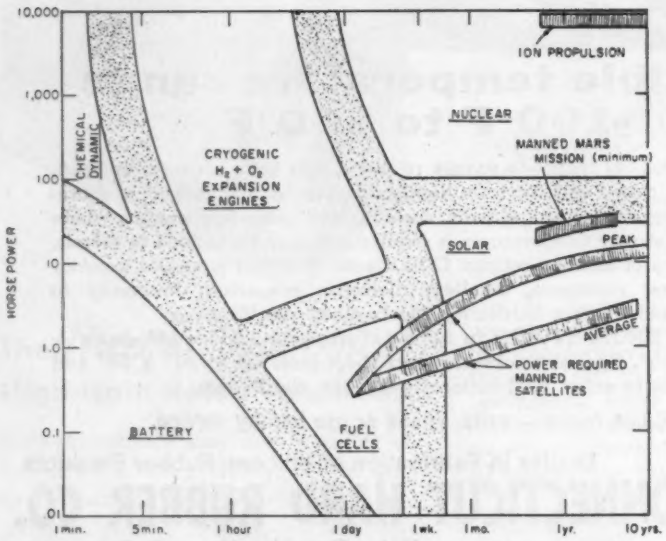

Fig. 1. Electrical power for space vehicles. Shown above are predicted minimum power requirements for several missions including manned satellites, a manned Mars mission (without propulsion) and ion propulsion. For satellite missions in the near future, existing for a few days up to two weeks, chemical systems will probably be used due to lower weight requirements, convenience of packaging and high inherent reliability. For longer durations chemical fuel weight becomes prohibitively large and systems based on solar or nuclear energy sources must be used. Regenerative chemical systems, however, will continue to be used for storage and peak power application.

A wide variety of power systems appear theoretically able to provide electrical energy to future space vehicles. The relative advantage of each system in terms of weight and other factors will depend on the success of hardware development programs being conducted today. In a paper presented at the 1960 Semi-Annual Meeting and Aviation Conference of ASME, Walter R. Menetrey, Staff Engineer and James D. Burns, Physicist at Electro-Optical Systems, Inc. Pasadena, Calif., emphasized the design characteristics and problem areas associated with some important solar power system components.

Electrical power for space vehicles will be supplied by chemical, nuclear or solar systems. As shown in Fig. 1, solar and nuclear systems are advantageous when power is required for durations longer than a few days, primarily because of the low energy capacity per unit weight of chemical fuels. Solar power systems are best at medium to low power levels. The break-even point between solar and nuclear systems is primarily determined by the large fixed weight of the nuclear reactor and shield required at any power level.

Some common energy converters and transformations are shown in Fig. 2.

PHOTOVOLTAIC SYSTEMS

Photovoltaic cells are presently being used in low power, non-oriented power systems. Future applications requiring higher power levels may use oriented solar cell arrays in conjunction with lightweight concentrators to increase the intensity of illumination. A prediction of the specific

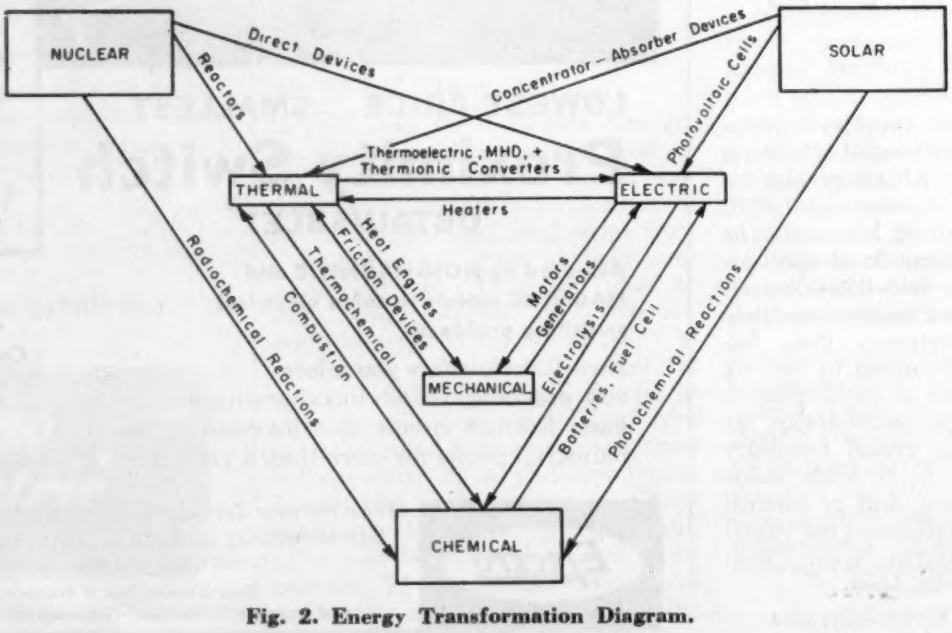

Fig. 2. Energy Transformation Diagram.

OWER SYSTEMS

weight of photovoltaic systems is shown in Fig. 3.

The assumptions used in calculating specific weight, shown in Fig. 4, are conservative and appear to be well within the possible engineering state of the art. A decrease in minority carrier lifetime due to bombardment with high energy protons and electrons has led to predictions of complete system degradation in periods of hours to days, depending on the location of the satellite. Protective glass covers about 50 mils thick have been predicted which increase systems weight by a factor of about two.

Optimum illumination intensity will depend on the surface characteristics of the solar cell and array structure, the solar cell efficiency as a function of temperature, solar intensity and related factors. Selected concentration ratio is a compromise between increased illumination of the cell surface and decreased cell efficiency at high temperatures. This is illustrated in Fig. 5 which shows the power output per unit area for several types of solar cells using the natural cell surface or multi-layer interference filters.

Weight savings realized by using concentrating mechanisms are shown in Fig. 6. It was assumed that the low concentration was provided by simple flat plate reflectors of the proper length and at the proper angle in resect to the array surface. Other shapes which provide the same concentration ratio for less surface area can be devised.

SOLAR CONCENTRATORS

Major system components used in a solar-thermal system

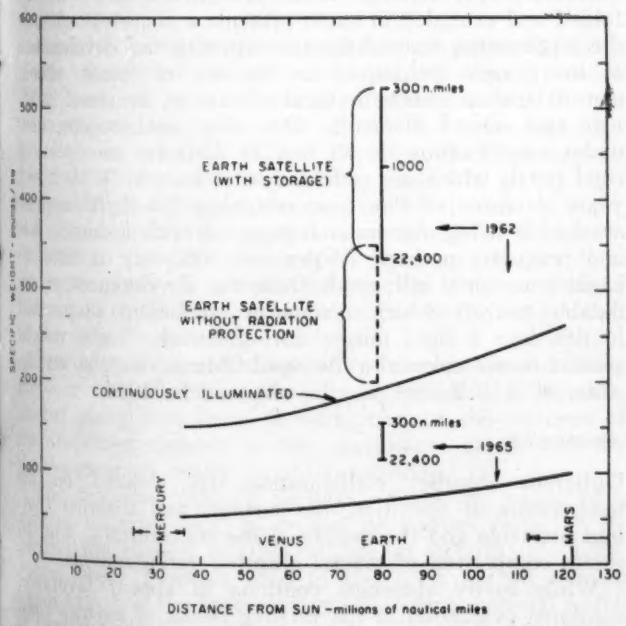

Fig. 3. Specific weight of photovoltaic power systems. Curves illustrate possible weights for systems constructed at the end of 1962 and 1965. Specific weights for the earth satellite include extra solar cell capacity for the darkness period, storage, control, regulation and orientation mechanisms.

are shown in Fig. 7 in a general schematic form. Solar-thermal systems appear favorable for application in the medium power ranges, roughly 1-20 kw. An important component and perhaps the least developed is the solar concentrator used to concentrate solar flux onto an absorber mechanism. Many analyses indicate the superiority of the single paraboloid mirror over other types for high efficiency, high temperature operation.

In practice, many types of errors will affect system performance. The effect of local surface deviations of the mirror surface is shown in Fig. 8.

Spread in the focal image relates analytically to the overall concentrator-absorber efficiency, as illustrated in Fig. 9. To compuete this figure the three sources of energy loss considered were: reradiation of energy from the entrance of a cavity absorber, some reflected sunlight not entering the cavity and obscuration of the center of the primary paraboloid mirror by the cavity absorber.

Other losses will be incurred by errors in the orientation mechanisms of the concentrator towards the sun. A mirror with perfect surface orientation errors of up to 1 degree could be tolerated using cavity entrance diameters anticipated in practical systems. For poorer mirrors even

SOLAR CELL	Material	1962 Silicon	1965 Silicon
	Efficiency (20°C)	12 percent	14 percent
SOLAR ARRAY	Weight (pounds/ft²)		
	Without radiation protection	0.5	0.2
	With radiation protection	.2	1.5
	Type	Ni-Cad Bat.	Regenerative Fuel Cell
STORAGE	Weight	4 watt hr/lb (90 Min.) 8 watt-hr/lb (24 Hr.)	15 whr/lb
	Efficiency	70 percent	80 percent
CONTROLS	Weight	40 lbs/kw	20 lbs/kw
	Efficiency	70 percent	80 percent
CONCENTRATOR	Type	None	Flat Plate

Fig. 4. Parameters for photovoltaic system design. Within a few years, regenerative fuel cells will be developed to the point where they can be inserted into operating systems. Estimated fuel cell storage weights vary considerably due to the lack of experimental data. 15 watt-hrs/lb was selected on the basis of analytical data and experiments performed by Electro-Optical Systems, Inc. using a hydrox fuel cell combined with an electrolysis unit. Control and regulation circuitry will weigh on the order of 40 lbs/kw with an efficiency of 70 percent, assuming ac of low harmonic content is required, based on the static devices presently being constructed for advanced aircraft. A decrease to 20 lbs/kw with an efficiency of 80 percent by 1965 was assumed.

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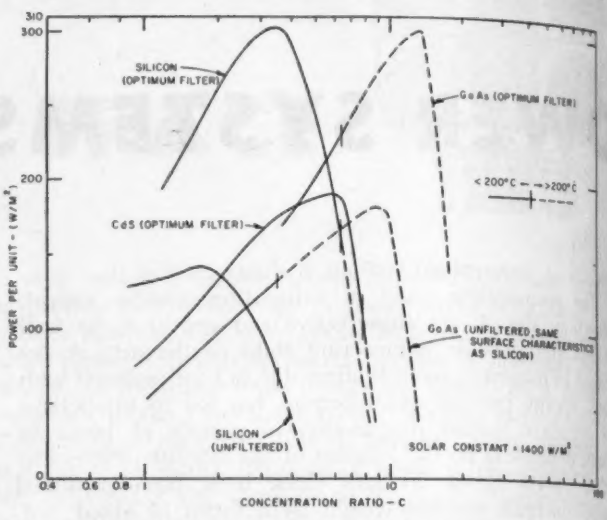

Fig. 5. Power/unit area vs. concentration ratio for solar cells. For currently available silicon solar cells with 12 percent efficiency at room temperature and without spectrally selective filters, an optimum concentration ratio of 1.86 will provide close to 180 watts/sq. meter in space. The same cell using highly developed spectrally selective filters will provide close to 300 watts per square meter at a concentration ratio of 3.5. Cadmium sulfide cell had a room temperature efficiency of five percent while the gallium arside cell had a room temperature of four percent. Dotted lines indicate those concentration ratios which would result in temperatures greater than 200 C which is roughly the upper limit beyond which severe degradation of solar cell performance results.

greater orientation errors could be tolerated.

No mirror, greater than a few feet in diameter, that combines high surface reflectivity, good surface accuracy and light weight suitable for space application has as yet been constructed.

Development of large diameter mirrors which can be folded and extended in space presents a major extension of the engineering state-of-the-art requiring the development of many new techniques in the use of foams, plastic materials, aluminum honeycombs, coatings, structural bondings and related elements. One solar concentrator, now under consideration, is 32 feet in diameter consisting of rigid petals which are unfolded after launch. Within two years a mirror of this type weighing 0.3 lb/ft² appears obtainable using aluminum honeycomb with a double skin and providing perhaps 70 per cent efficiency at 1200 F. Lighter weights will result from the development of inflatable mirrors which assume a paraboloid shape and harden into a rigid mirror during launch. Light weight plastic foams may also be used. Mirror weighs on the order of 0.15 lbs/ft² may be obtained by 1965.

ABSORBER

Optimum absorber configuration will depend on the temperature of operation, the surfaces and absorber coatings available and the quality of the concentrator. Fig. 10 shows comparison of several absorber configurations.

While cavity absorbers continue to appear favorable, continual evaluation of the relative merits of cavities compared to other shapes will be necessary, particularly if developments in spectrally selective surfaces advance rapidly. It should be noted that operations in higher temperatures, such as in solar-thermionic emitter systems, favor the use of the convex absorber configuration.

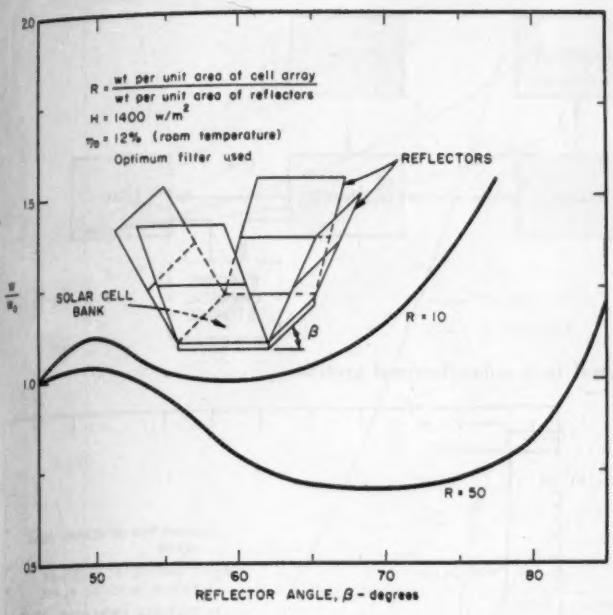

Fig. 6. Ratio of system weight with reflectors to weight without reflectors. Weight savings on the order of 30 percent appear reasonable if a ratio of reflector to solar cell array weight of 1-50 can be achieved. For an array weight of 2 lbs/ft², this would require 0.04 lbs/ft² for the concentrator. This weight appears reasonable using aluminum foil stretched over thin wire frames.

THERMIONIC EMITTER

The major types of heat engines being considered for use in solar-thermal systems are the Rankine cycle turbine, Stirling engine, thermocouple and thermionic emitter. Due to its light weight, high current density, high operating temperatures, and anticipated high efficiency, the thermionic diode is of particular interest to future power system development.

Using low pressure cesium vapor to neutralize the space charge, thermionic diodes have been constructed having 1000 hours or more life with a power output of one watt/cm2 and an efficiency of about 7 per cent. Researchers in this field believe that the efficiency can be raised to 10 per cent using existing materials.

Operating temperature depends on which cathode material is being used; to date, the successful diodes have been operated in the 1300 K to 1500 K range. Higher temperatures result in greater efficiencies but cause rapid deteriation of the tube performance due to the evaporation of the cathode material.

In order to increase the operating temperature and hence increase the efficiency, research is currently being conducted along two lines; the adoption of the concept of the dispenser cathode to the thermionic diode and the development of better emitting materials.

The dispenser cathode method utilizes the vapor of a coating material such as cesium or barium oxide to replenish the coating on the cathode as it boils off. Difficulties occur however, due to the need for an ionized vapor to reduce the space charge. A coating material which is readily ionizable, such as cesium, also evaporates easily, necessitating such a high vapor pressure for the replenishment of the cathode coating that a high voltage drop occurs across the tube due to electron-vapor particle collisions. On the other hand, materials which do not evapo-

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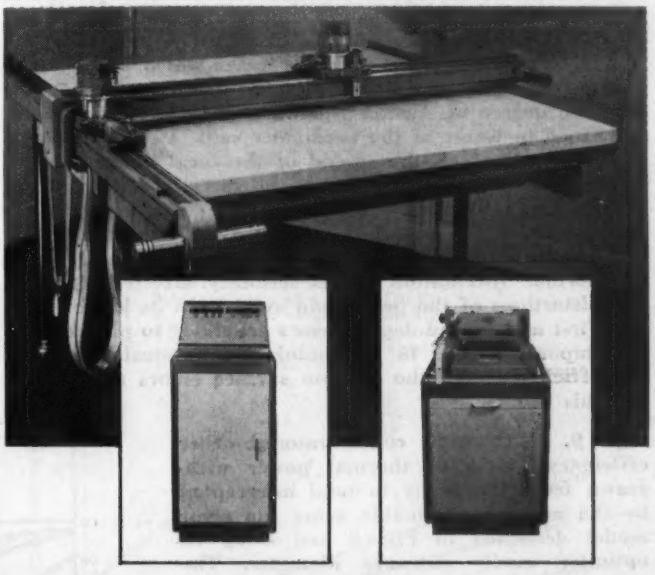

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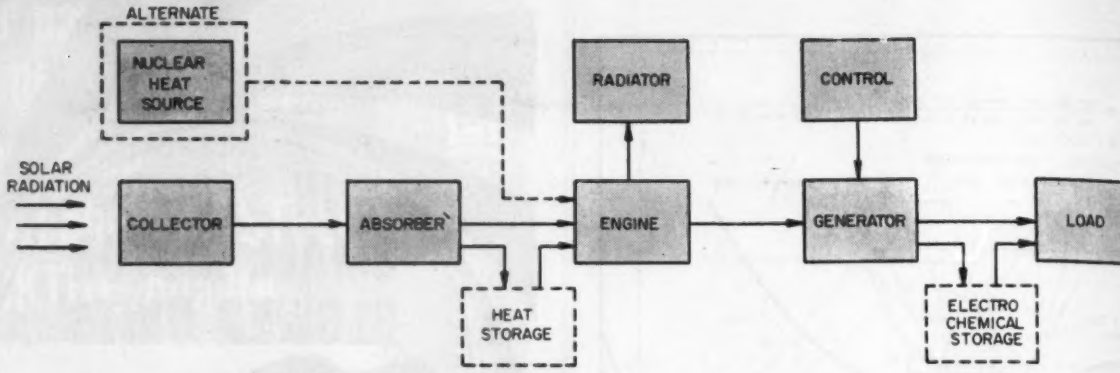

Fig. 7. Major system components used in a solar-thermal system.

rate easily, such as barium oxide are difficult to ionize.

Practical emitters fall close to their theoretical potential using materials such as tantalum, tungsten, thorium, and molybdenum. Recently there has been considerable interest in the refractory compounds such as zirconium carbide. If the theoretical potentialities could be realized in practice (so far this has not been the case), diodes of very high power output with efficiencies of over 30 percent would become quite feasible.

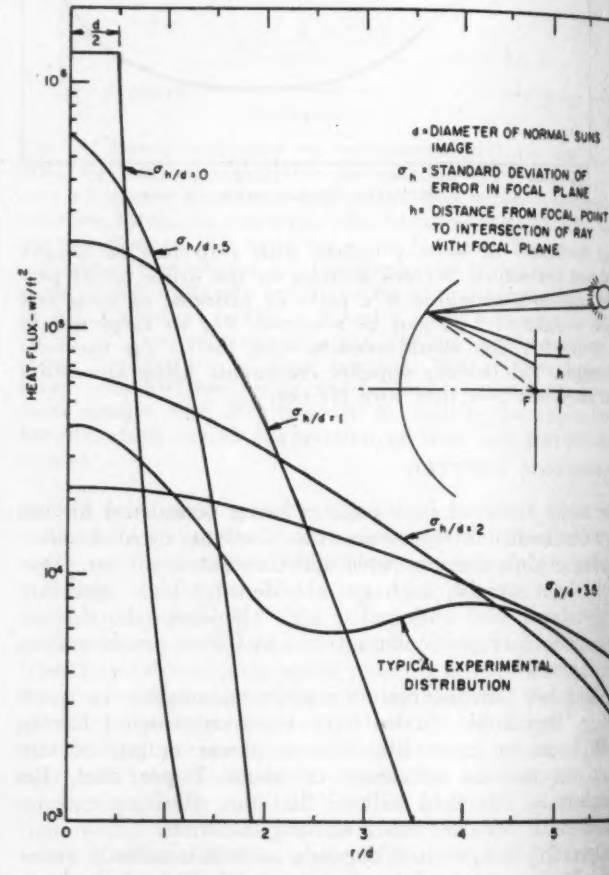
d = DIAMETER OF NORMAL SUNS IMAGE
σ_h = STANDARD DEVIATION OF ERROR IN FOCAL PLANE
h = DISTANCE FROM FOCAL POINT TO INTERSECTION OF RAY WITH FOCAL PLANE
HEAT FLUX - wt/ft²
$\sigma_{h/d}$ = 0
$\sigma_{h/d}$ = .5
$\sigma_{h/d}$ = 1
$\sigma_{h/d}$ = 2
$\sigma_{h/d}$ = 3.5
TYPICAL EXPERIMENTAL DISTRIBUTION
r/d

Fig. 8. Effect of mirror error on flux density at focal plane of paraboloid. It was assumed that the distance from the focal point of the paraboloid mirror to the intersection of the reflected ray with the focal plane was described by a normal probability distribution. σ_h is the standard deviation of this distribution and d is the diameter of the normal sun's image which would occur on the focal plane if the mirror surface were perfect. The degree of surface roughness therefore, can be defined in terms of the parameter σ_h/d. As this figure of merit increases, the spread of the focal image also increases. The distance h can be directly related to an angular deviation of the mirror surface. Optical measurements have indicated that the flux distribution on the focal plane is not described too closely by a normal distribution but is seriously affected by gross distortions of the paraboloid away from its ideal shape. First and second degree errors are likely to play a more important role in determining concentrator-absorber efficiency than the random surface errors assumed in this model.

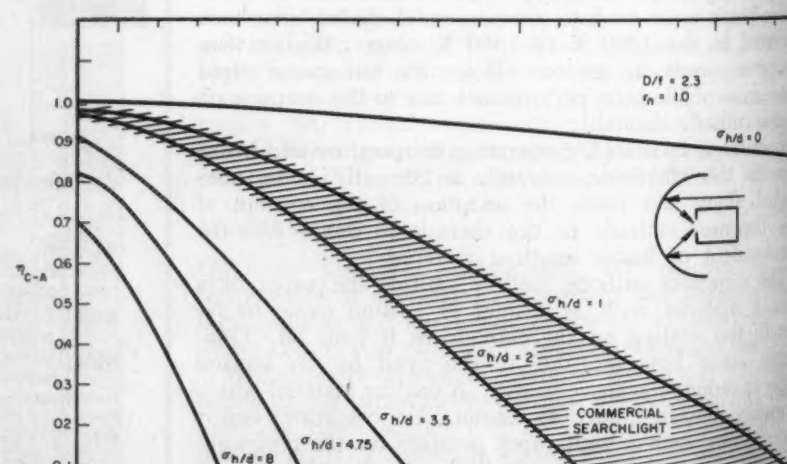

Fig. 9. Maximum concentrator-absorber efficiency (ratio of thermal power withdrawn from the cavity to total intercepted by the mirror) obtainable using the error model described in Fig. 8 and using an optimum cavity entrance diameter. The reflectivity of the mirror was considered to be 1.0, while in practice it will be closer to 0.9. As shown, efficiency will decrease as the temperature increases and for poor mirrors, definite limitations on the temperature obtainable with the best type of absorber exist. Measurements conducted at Electro-Optical Systems, Inc. indicate that commercial searchlight mirrors have a quality of roughly that shown by the shaded region. With a maximum effort devoted toward solar concentrator improvement, it now appears possible to fabricate in the near future, lightweight solar concentrators with a surface quality roughly comparable to the poorest commercial searchlight.

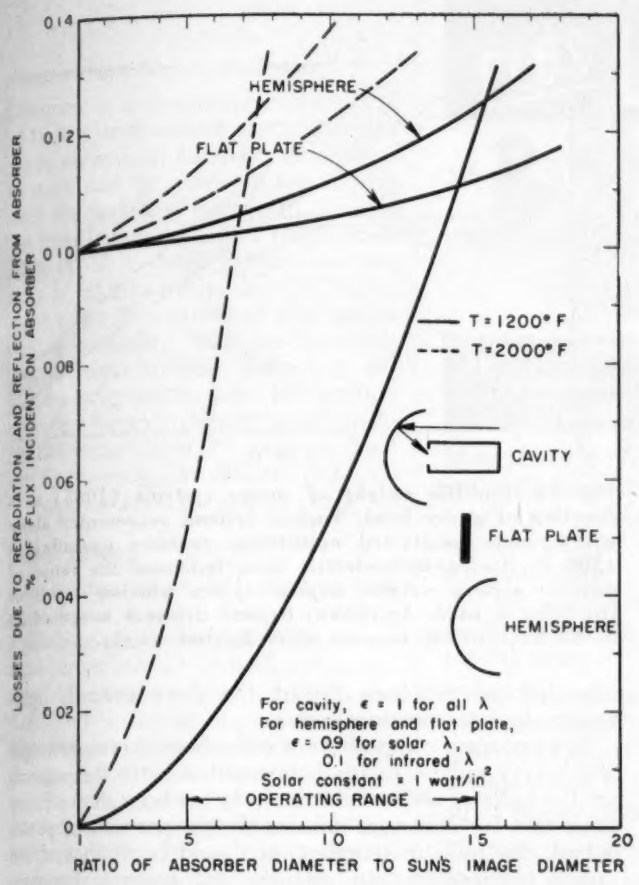
HEMISPHERE
FLAT PLATE
T = 1200° F
T = 2000° F
CAVITY
FLAT PLATE
HEMISPHERE
For cavity, ε = 1 for all λ
For hemisphere and flat plate,
ε = 0.9 for solar λ,
0.1 for infrared λ
Solar constant = 1 watt/in²
OPERATING RANGE
LOSSES DUE TO RERADIATION AND REFLECTION FROM ABSORBER
% OF FLUX INCIDENT ON ABSORBER
RATIO OF ABSORBER DIAMETER TO SUN'S IMAGE DIAMETER

Fig. 10. Percent loss vs. absorber size. Reradiation losses from a cavity are compared to the reflection losses from convex shapes which use spectrally selective surfaces of an advanced type, i.e., emissivities of 0.9 for solar wavelengths and 0.1 for infrared wavelengths and stability at high temperature operation. These surfaces are presently beyond the state-of-the-art for high temperature operation but will soon be developed.

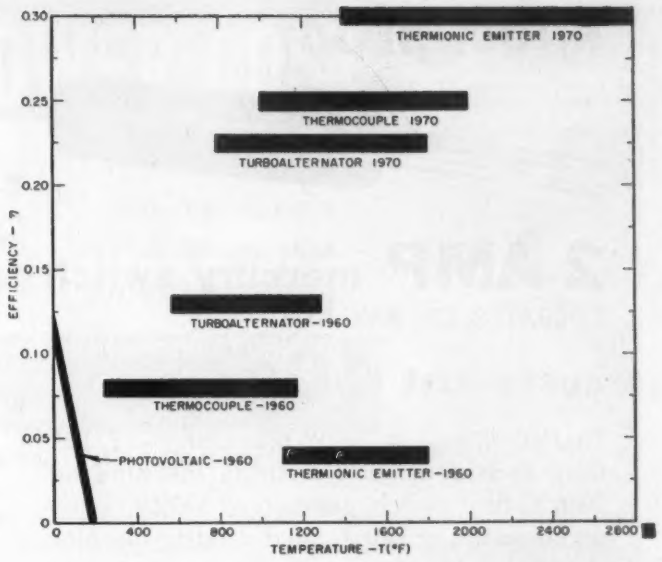

Fig. 11. Energy converter efficiencies. High temperature represents the upper limits of operation due to materials limitations, while the low temperature is chosen for minimum system weight. The Stirling engine, not included above, offers considerable promise due to its high operating efficiency. Solar-Stirling engine systems offer minimum weight at a temperature range between 1260 F (melting point of lithium hydride thermal storage unit) and 150 F (wet radiator using water coolant). In this range the engine will operate at greater than 30 percent efficiency. An engine specifically designed for space is currently being fabricated and no major difficulties are foreseen based on operating experience with ground models.

SYSTEMS COMPARISON

Any comparison of solar-thermal systems will depend on the efficiency and the temperature ranges of operation of the heat engine used. Fig. 11 shows the ranges of efficiency and temperatures used at present and anticipated in 1970. The efficiency was assumed to increase in a linear fashion each year. At present the turboalternator offers a higher efficiency than either type of static heat engine. Predictions indicate that this situation will be reversed within a decade.

Solar-thermal systems may use thermal storage due to its potentially higher storage capacity. Lithium hydride has the highest thermal capacity (312 watt-hr/lb) but melts at a relatively low temperature (1260 F). Other higher melting point materials such as lithium fluoride, sodium fluoride, beryllium and silicon have less thermal capacity than lithium hydride by a factor of two or more.

A great deal of development work is still required before a practical thermal storage unit can be constructed. Lithium hydride, for example, will dissociate unless high pressures are maintained. Silicon is extremely difficult to contain for long periods of time. Lithium hydride expands 16 percent by volume upon melting, necessitating some mechanism to insure against excessive pressures and withdrawal of solid material from chamber walls. These and

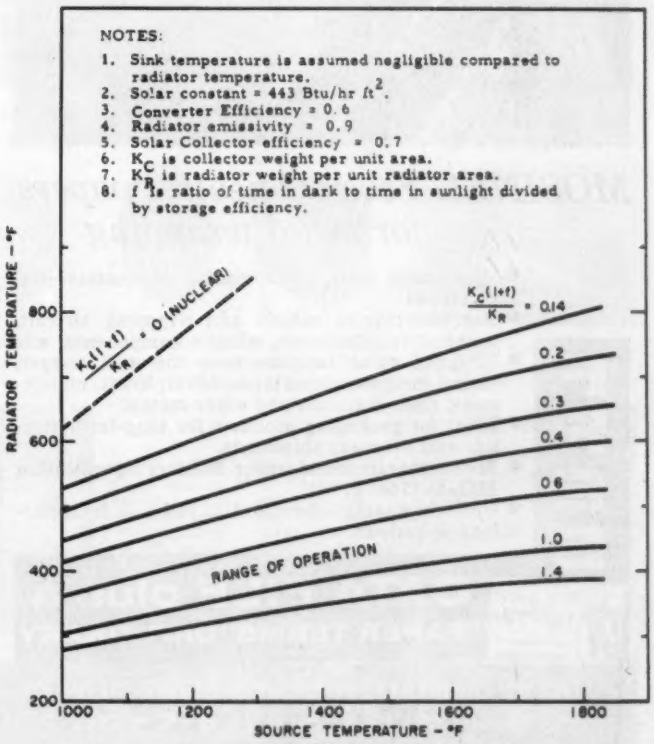
NOTES:
1. Sink temperature is assumed negligible compared to radiator temperature.
2. Solar constant = 443 Btu/hr ft².
3. Converter Efficiency = 0.6
4. Radiator emissivity = 0.9
5. Solar Collector efficiency = 0.7
6. K_C is collector weight per unit area.
7. K_R is radiator weight per unit radiator area.
8. f is ratio of time in dark to time in sunlight divided by storage efficiency.
K_C(1+f)/K_R = 0 (NUCLEAR)
K_C(1+f)/K_R = 0.14
0.2
0.3
0.4
0.6
1.0
1.4
RANGE OF OPERATION
RADIATOR TEMPERATURE - °F
SOURCE TEMPERATURE - °F

Fig. 12. Optimum radiator temperature for minimum solar APU weight

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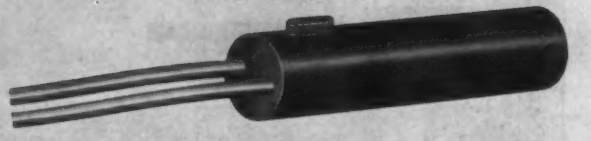

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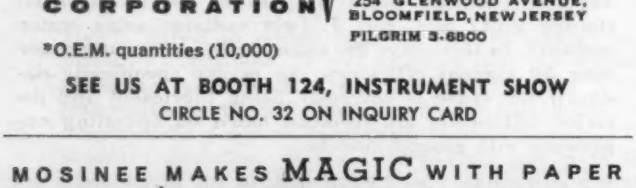

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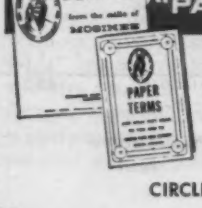

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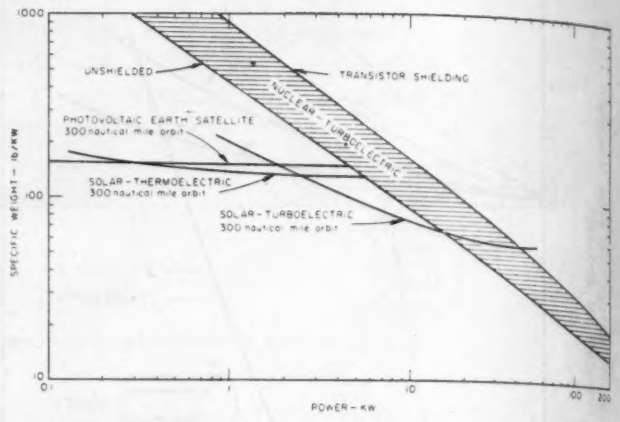

Fig. 13. Specific weight of power systems (1965) as a function of power level. Nuclear systems represented above use hydride moderated epithermal reactors operating at 1300 F. Nuclear-turboelectric zone indicated the range of nuclear system weights dependent on whether transistor shielding is used. As shown, beyond a power range of 30 to 50 kw, nuclear systems offer lightest weight.

other related problems thwart the drive towards lightweight, high temperature systems.

The two main components of solar-thermal system weight which vary radically with source and radiator temperature are the radiator and concentrator. It has been shown many times that for minimum radiator weight per unit of power output, the radiator temperature should be ¾ that of the source temperature. In solar-thermal systems, however, the necessity for a lightweight concentrator demands a high efficiency system with a lower radiator temperature. This point is emphasized in Fig. 12 which displays the optimum radiator temperature for minimum combined radiator and concentrator weight, using a specific converter efficiency of 60 percent of Carnot. Typically in the 1960-65 period, concentrator weight will be 0.3 lbs/ft², radiator weight will be 1.0 lbs/ft² and the ratio of dark time to time in sunlight will be on the order of 40 percent. In practice, optimum radiator temperature will depend a great deal on specific converter characteristics.

Based on the assumptions discussed above, systems analyses were performed to obtain estimates of specific weight of several systems as a function of power level. For systems which might be obtainable in 1965 a photovoltaic system was particularly favorable for low power levels, however, the cost of this system is high. High efficiency cells may cost on the order of $200 per watt. Solar-turboelectric systems will offer weight advantages in the medium power levels of 10–20 kw. Calculations assume the use of lithium hydride storage which limits the heat source temperature to 1260 F.

Other solar power systems may offer weight advantages at low power levels. A solar-thermoelectric system (using 13 percent efficient thermocouples) is shown in Fig. 13. An estimate of systems using the thermionic emitter and Stirling Engine resulted in weights close to the thermoelectric system.

The assumptions necessary for system design are too uncertain to draw definite conclusions regarding the weight superiority of one type of converter over another. It is likely that the solar systems in the 100 watt to 10 kw region will be selected on the basis of reliability, packaging and other factors rather than weight, as no system, it seems, displays an overwhelming weight advantage.

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Servo Drives

Subminiature servo drive system consists of a solid state servo amplifier, a precision gear train and a high torque servo drive motor. Overall cubic volume of the entire system is 1.75 in. and it delivers a torque of two in.-lbs. at the servo actuating arm from a voltage change of 0.001 volt. System provides a servo actuator arm speed of 270° of rotation per second. The unit was designed for military and industrial applications requiring accurate, high speed, proportional control. Solidtronics Div., Electrosolids Corp., Van Nuys, Calif.

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Analog Programmer

Arbitrary function generator called the 75- Analog Programmer, converts any single-valued function, drawn on graph paper with conductive ink, to a proportional voltage as a function of time. Unit has an accuracy of 0.5% and a response time of less than ten microseconds to full scale. The analog programmer consists basically of a chart-supporting drum, a resistive roller or potentiometer and two contact rollers. A synchronous motor working through a gear assembly provides the driving force for the chart drum. Selection of the proper drum speed, together with appropriate length of curve provides a wide variety of program time conditions. At any specific instant of time, the output voltage (Y) is proportional to the drawn curve. The X axis varies linearly with time when the drum is driven by the constant speed synchronous motor. However, a servo motor can be incorporated to provide the driving force making the drum position a function of an independent variable. American Measurements & Control, Inc., Waltham, Mass.

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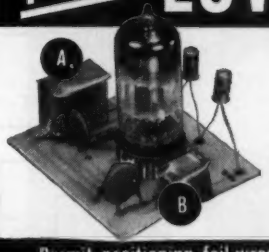

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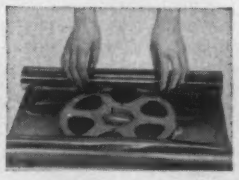
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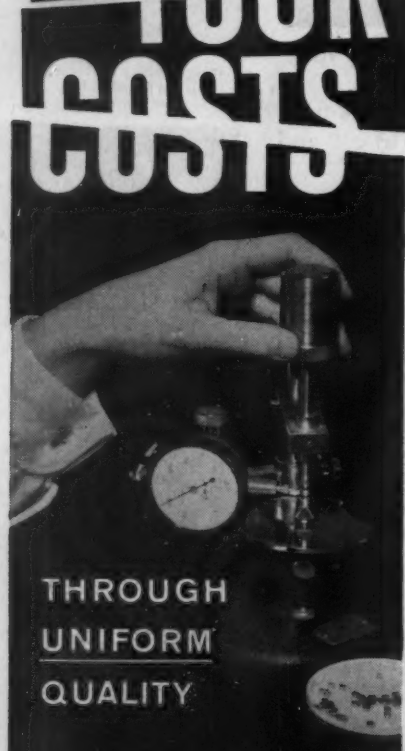
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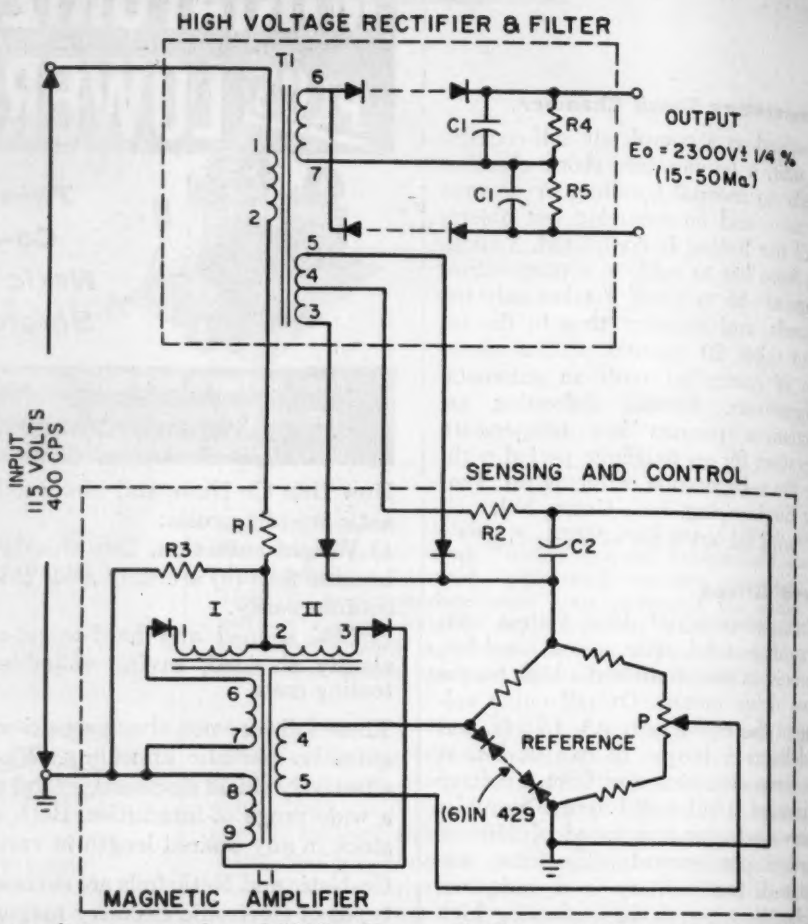

Schematic representation of 2300 volt magnetically regulated power supply shows chassis isolation of high voltage rectifier and filter from sensing and control section.

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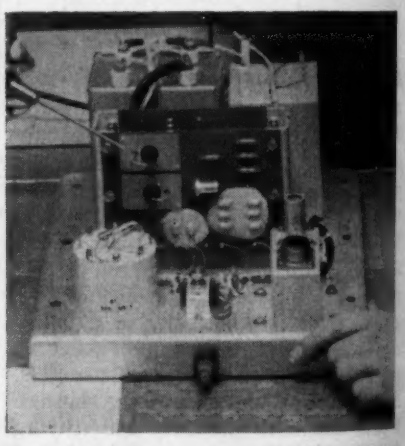
Output voltage is maintained to design accuracy with variations in line voltage from 105 to 130 volts, with load current changes of 15 to 50 ma., and over an ambient temperature range of −40 to +85C. Nominal input to the power supply is 115 volts at 400 cycles. Over a restricted temperature range and with added refinements, this circuit has regulation capabilities of ±1/10%. Measured efficiency at full load is 82% and both the step-up transformer and high-voltage capacitors are oil-filled. The magnetic amplifier is cast in silica-filled epoxy resin for environmental protection. Bell Tel. Laboratories, New York, N. Y.



Bell Tel. Labs.' magnetically regulated high voltage power supply.

CIRCLE NO. 34 ON INQUIRY CARD

Stepper Motors May Someday Replace AC and DC Servo Motors

In many servomechanism applications, the available input quantity is in the form of a pulse signal. A useful device in such cases is a stepper motor, which converts pulse signals directly to angular displacements. One of several such motors manufactured by the Instrument Division of American Electronics, Inc., is described in Fig 1. A block diagram of the logic circuitry for driving the motor is shown in Fig. 2.

Stepper motors also offer advantages in analog servo systems. In the opinion of Jack F. Hellner, Systems Engineer at American Electronics, stepper motors, with their zero overshoot, high acceleration, high stall torque, and insensitivity to varying loads, can out perform their analog counterparts in position servo applications by a considerable margin. He goes so far as to say it is conceivable that, with the advent of economical circuitry and high speed stepper motors, the now popular ac and dc servo motors may become obsolete in the near future.

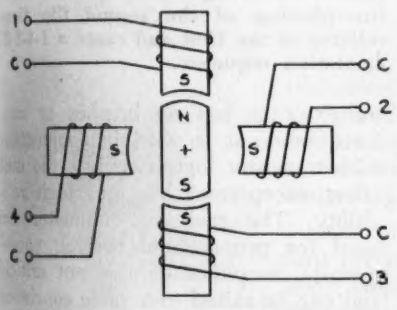


Fig. 1. American Electronics' stepper motor, capable of more than 180 steps per second and producing an output shaft speed of 2700 rpm, consists of a four pole stator and a permanent magnet rotor. When voltage is applied to terminal (1) the resulting magnetic flux positions the rotor as shown. If the voltage is removed from terminal (1) and applied to terminal (2) the rotor will rotate clockwise 90 degrees. Thus as voltage is applied consecutively to terminals 1-2-3-4 the rotor will continue to move in a clockwise direction in 90 degree steps. Reversing the winding excitation sequence to 1-4-3-2 produces counterclockwise rotation.

Mr. Hellner's opinions are based on experience in developing circuitry for many stepper motor applications in position servos with either ac or dc error signals.

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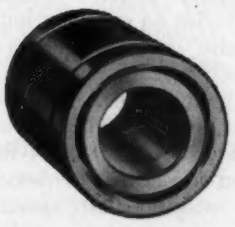

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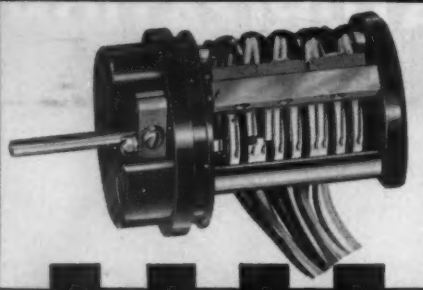

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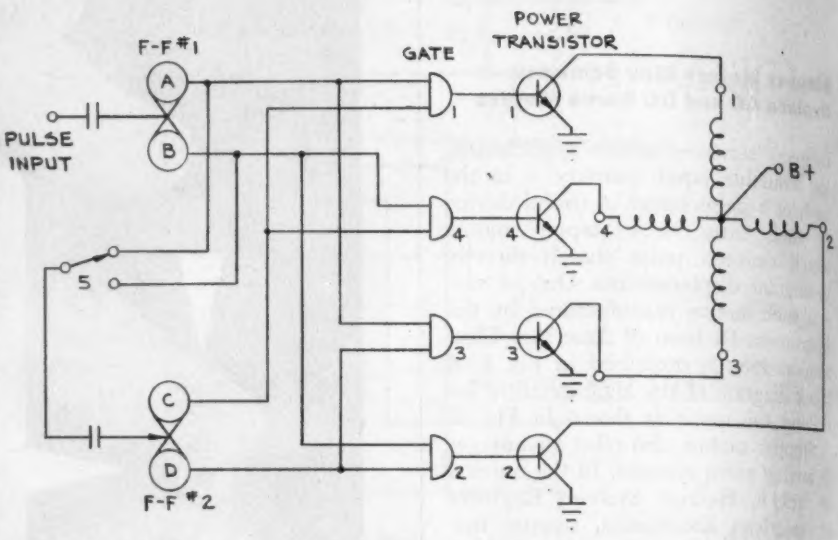

Fig. 2. Block diagram of the logic circuitry used to drive a four pole stepper motor. To analyze its operation, assume transistors A and C are cut off. In this state, only gate (1) receives two positive inputs which allow power transistor (1) to supply current to winding (1). An input pulse reverses the first flip flop sending transistor B into cut-off. With switch 5 in its indicated position a negative pulse is coupled to the second flip flop, sending D into cut off also. Now transistors B and D supply positive signals simultaneously into gate (2), turning on winding (2). Another input pulse reverses the first flip flop, coupling a positive pulse to the second flip flop which has no effect. Transistors A and D are now cut off so that gate (3) allows power transistor (3) to conduct. The next input pulse causes both flip flops to reverse once again and the resulting positive signals from B and C allow gate (4) to operate. Since two (2) flip flops provide only four possible combinations of two (2) gate voltages the cycle will repeat for additional input pulses. Reversing switch 5 will change the phasing of the second flip flop relative to the first and cause a 1-4-3-2 excitation sequence.

Typical of such applications at American Electronics is a servo package (Fig. 3) used by missile manufacturers to tune a radar klystron to a precise frequency. It consists of an error-sensing device an amplifier-logic circuit and a pulse motor. When a desired frequency is reached, the receiver "gates" the logic circuit, stopping the pulse motor instantly. The system then "locks" the klystron shaft until the gate is released and a new frequency is selected. Full output shaft speed is attained after one pulse input and pulse rates to 200 per second are feasible. Since the pulse motor has no brushes or contacts, when it is used in conjunction with transistor logic circuitry, the unit offers exceptional life and high reliability. The package eliminates the need for proportional control; consequently, amplifier gain is not critical and can be raised to a value consistent with the desired system performance.

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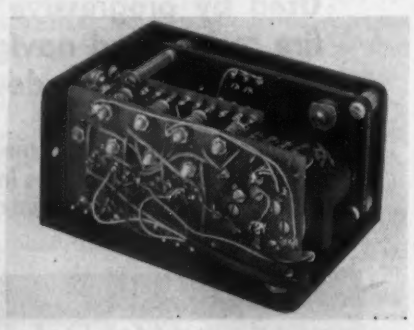

Fig. 3. Stepper motor system tunes radar klystron to precise frequency.

Dynamic Balancer

Designed to meet the precision balancing needs imposed by the miniaturization of gyros, a dynamic balancing machine determines unbalance vibrations as small as ¼ of one-millionth of an in. Machine's speed permits production-line precision balancing of miniature gyro rotors. Balancer can accommodate rotors of diameters up to 2½ in. and weighing up to 16 oz. The instrument discriminates between bearing noise and unbalance vibrations. By plugging in auxiliary equipment such as a panoramic analyzer, bearing vibrations can be analyzed. Micro Balancing, Inc., Garden City Park, N.Y.

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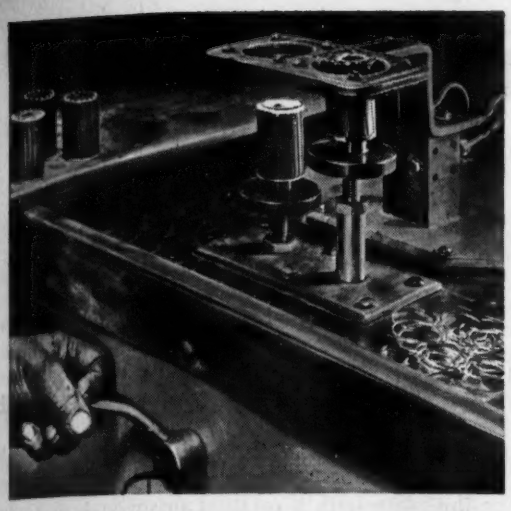
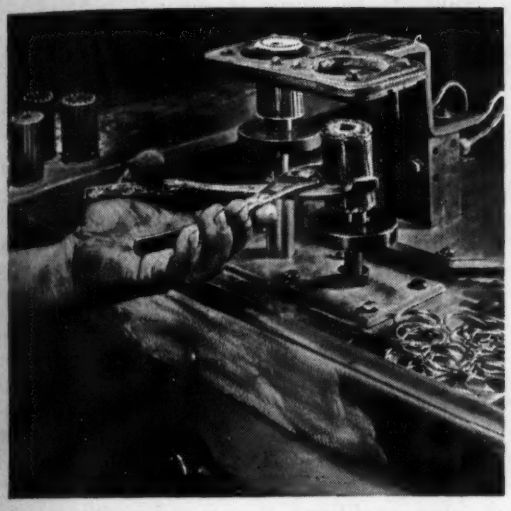
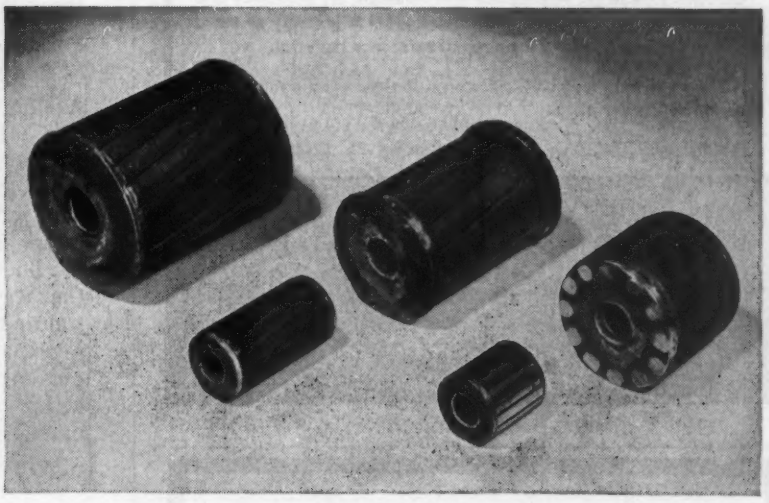


Handy & Harman Sil-Fos Silver Brazing is Used by Induction Motors Corp. in 5427 Different Motors





Induction Motors Corp. of Westbury, New York, and Maywood, California, has built an outstanding reputation as a designer and manufacturer of sub-fractional horsepower motors...for 5427 high performance reasons.

This large variety of motors, blowers and fans for an equally large variety of applications, stems from 15 basic motor frame sizes, depending on length, pole materials, windings, groove angles and the like.

Handy & Harman silver alloy brazing is concerned with brazing the rotors. Each rotor (whatever the size) is joined by a preformed ring of Handy & Harman SIL-FOS, by induction heating – at an alloy cost that is reckoned in pennies. For example, the alloy cost per ⅞" frame is two cents per joint, or four cents per complete assembly.

That's an example of the economics of silver alloy brazing. Performance requirements are quite another thing – and they are unquestionably stringent. Many of these motors are used in aircraft and missile work and must, of course, meet the most extreme environmental conditions.

Strength alone would be reason enough to discuss the merits of silver alloy brazing... and to point out as a reason for its wide acceptance throughout industry. The facts are that there are many more benefits; gas- and leak-tightness, thermal and electrical conductivity, ductility, and production economy – are all *joint qualities* of silver alloy brazing. At any time, we will be happy to discuss any or all of these qualities (and others), as applied to your product or production method. The benefits are large and you can enjoy them.

FIRST, BULLETIN 20

This informative booklet will get you off to a good start on the values, techniques and economies of low-temperature silver brazing. A copy awaits your request.

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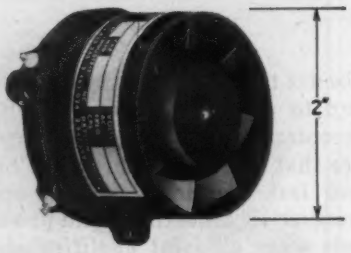

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VAX-2-MM. Designed for 41 cfm. @ 1.5" H_2O back pressure, unit operates on 26 v.d.c., but other versions may be wound for up to 115 v.d.c. operation. Length is 2"; weight is 5 oz. Flange mounting. Designed for MIL specs.

Request Bulletin VAX-2 from Globe Industries, 1784 Stanley Avenue, Dayton 4, Ohio.

GLOBE INDUSTRIES, INC.

CIRCLE NO. 38 ON INQUIRY CARD

NEW TECHNIQUES

SCANNING PHOTOMETER

Density vs Wavelength Curves of Spectrum Displayed on Oscilloscope

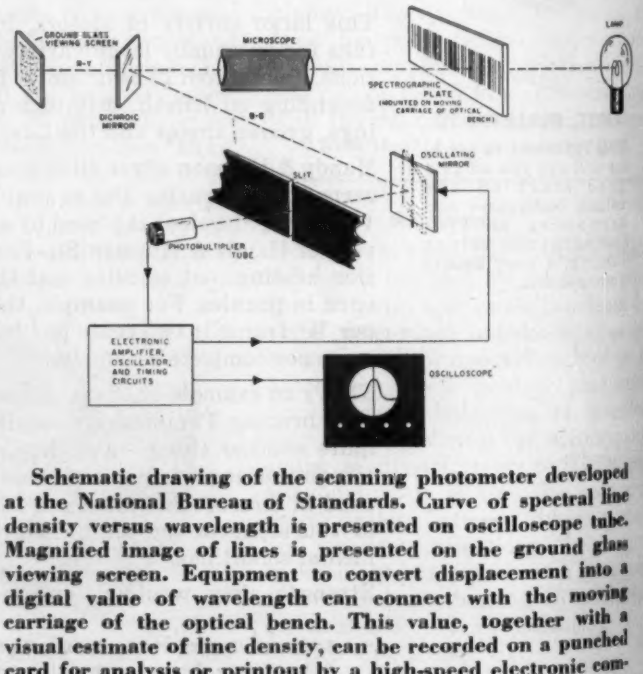
For many years the conventional method for reading spectrographic plates has been a time-consuming procedure susceptible to human error. Through a fixed microscope an operator located the center of a spectral line as well as possible.

A photometer, devised by M. L. Kuder of the National Bureau of Standards, based on an electronic scanning device, scans the plate with a rotating prism and presents the density vs wavelength curve as an oscilloscopic trace.

OPERATION

A lamp illuminates one side of the plate and on the other side a 10-power microscope is trained on a limited area of the spectrum. Immediately behind the microscope is a dichroic mirror that splits the image into two components: one, red-yellow and the other, blue-green. The red-yellow image is reflected to a ground glass viewing screen which provides the operator with a visual check of the portion of the spectrum being scanned. The blue-green image is transmitted to a vibrating mirror which reflects an oscillating image through a narrow slit to an end-on photomultiplier tube. The vibrating mirror provides the scanning action of the system and the phototube "sees" only a 13-micron width of the spectrum at any given time although a total width of 0.5 mm is being scanned.

The electrical output of the tube is fed to an electronic network containing amplifying, timing and positioning circuits. The resulting density-versus-wavelength curve is presented together with a fiducial line on the face of an oscilloscope tube. The fiducial line aids in locating the exact center of the spectral line. Wavelength is determined by measuring the displacement of the plate from a known starting point.



Schematic drawing of the scanning photometer developed at the National Bureau of Standards. Curve of spectral line density versus wavelength is presented on oscilloscope tube. Magnified image of lines is presented on the ground glass viewing screen. Equipment to convert displacement into a digital value of wavelength can connect with the moving carriage of the optical bench. This value, together with a visual estimate of line density, can be recorded on a punched card for analysis or printout by a high-speed electronic computer.

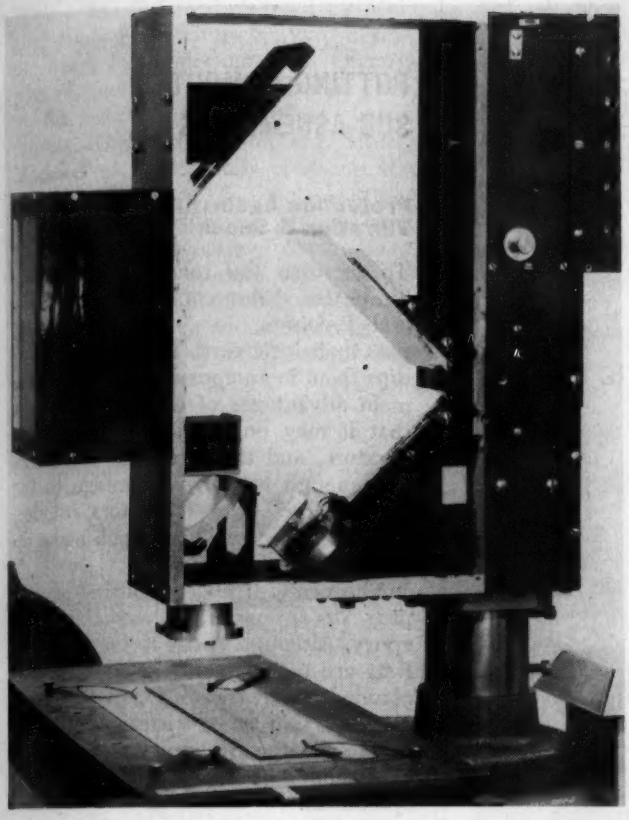


Fig. 2 Internal view of the optical scanning system. Spectrographic plate lies flat on carriage at bottom and is illuminated from underneath. Immediately above plate is microscope lens system and then the dichroic mirror. To right scanning action. Box at middle left holds ground glass viewing screen; box at upper right contains phototube.

The horizontal sweep of the oscilloscope (corresponding to the scan along the spectrographic plate), the vibrating mirror and the fiducial line generator are all driven by the same oscillator and the phase relation between the three is constant. Thus the display holds steady and is completely free from drift. The curve moves only when the carriage carrying the plate is manually shifted on the optical bench to examine another portion of the spectrum.

Although only one phototube has been mentioned, the instrument actually has 5 such tubes, one to detect each of the 5 separate spectra that are usually photographed side by side on a single plate. An operator can examine any one of the spectra simply by turning a 5-position switch. Two of the spectra are standards with the most prominent lines previously measured precisely on an interferometer. The presence of these lines on the plate gives the operator a set of calibrated points between which he can interpolate to determine accurately the wavelength of the lines appearing in the three unknown spectra.

National Bureau of Standards is developing equipment that will locate spectral lines and measure their densities electronically. When this equipment is completed, the reading of spectrographic plates will be entirely automatic.

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COOLING RADIATORS

Improved Construction Provides Higher Efficiency

Application of jeweler's skills is helping to solve the ever increasing problems of heat dissipation in miniaturized electronic equipment. Cooling radiators that absorb the heat of electronic tubes and dissipate it to the atmosphere are being made by the Baker Setting Division of Englehard Industries, Inc.

The cooling radiators, built to fit around electronic tubes, are generally made of copper and assembled with silver brazing alloys. A gold brazing alloy is often used to bond the electronic tube to the radiators.

Most of the cooling units operate by radiation or convection, or a combination of both. Units consist of a series of sheet metal fins formed around a hollow core into which the tube fits snugly, or others, which work by fluid convection, are designed with a series of hollow connecting chambers through which water passes.

The Baker Setting Division has evolved a number of construction techniques which improve the radiators' efficiency, make them extremely rugged, and cut their cost. One unit consists of radial wires set in holes bored in a ring. This design required much expensive hand work, but drawing on their experience in producing jewelry blanks, the company worked out a way to stamp out the radials in sets and then expand a central ring over their joined inner ends. This cut per-unit cost substantially.

In some small radiators the fins are formed as a continuous zigzag strip in such a way that, when they are bent in circles, the ends come together perfectly against the side of the ring. The ends are brazed simultaneously when the ring is brazed to the fins' edges. Previously, the ends often met in the middle of a fin, remained unbrazed, leaving a weak spot in the assembly.

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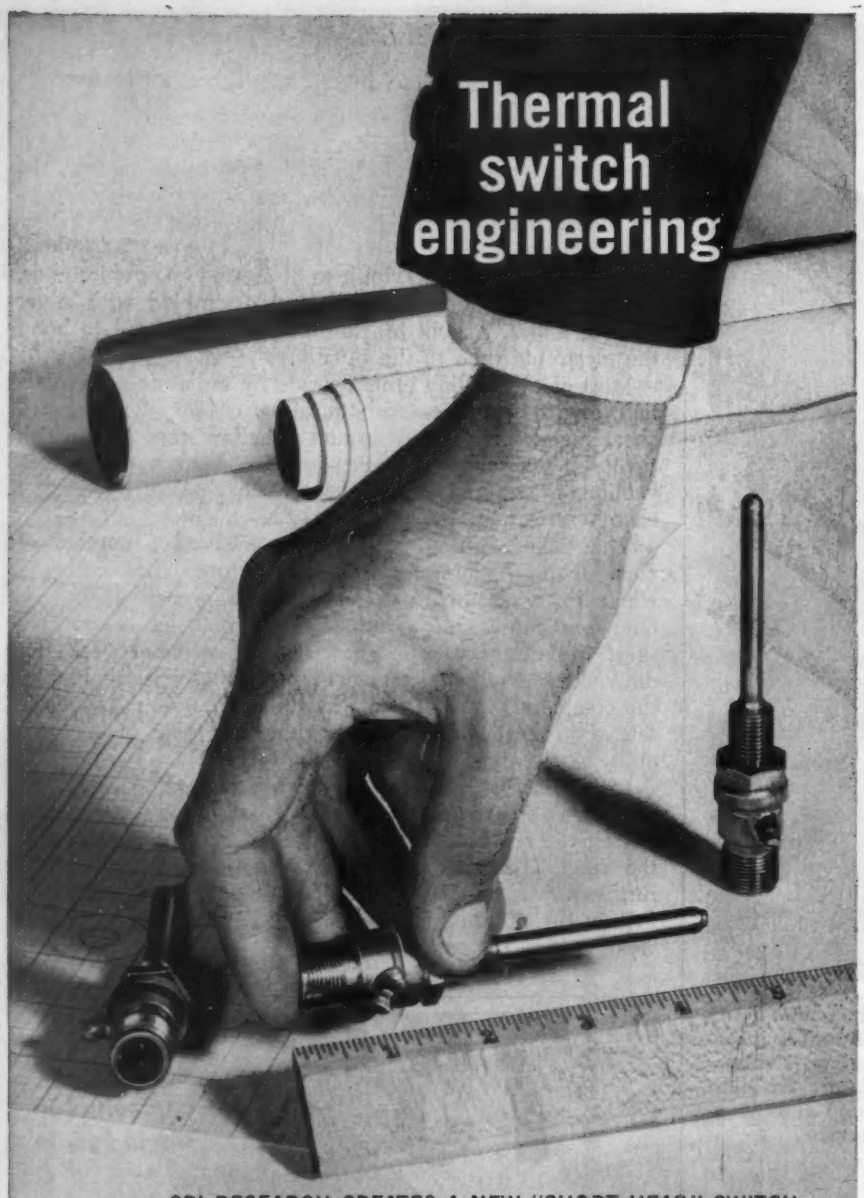

CPI RESEARCH CREATES A NEW "SHORT HEAD" SWITCH

From CPI research comes this new thermal switch with the shortest head construction of any AN connector type switch. This hermetically sealed, field adjustable, probe type switch was developed for an aircraft manufacturer to control inlet air temperature for heating and turbine exhaust temperatures for air conditioners.

There are other uses, too—controlling temperatures of gas turbines and heat exchangers or oil in gear boxes—in fact, many places where there's need for a hermetically sealed switch with a fast, easy electrical connection. It is possible that this or the many others developed by CPI specialists may not solve your problem. If not, CPI research can create the switch that will! Send your specs.

This new switch is constructed of all high temperature alloys and has a calibration range of −20F to 1750F with safe momentary overshoot to 2000F and undershoot to −100F. It is available in a variety of threaded and plate mountings. Mention "Spec-Stat" when inquiring.

CPI

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CIRCLE NO. 42 ON INQUIRY CARD

POTTING COMPUTER SUB-ASSEMBLIES

Protection Against Contamination, Vibration & Shock

To increase the reliability of digital computers, Librascope Division, General Precision, Inc., Glendale, Calif., pots their logic cards in pairs, and then dips them in an epoxy resin. One of the main advantages of the epoxy resin is that it may be applied at room temperature, and then set at temperatures low enough to prevent damage to the sensitive precision transistors, diodes, resistors and capacitors which make up the logic card circuits.

The coating process consists of dipping or spraying the assembly with epoxy. Although epoxy resins and catalysts are toxic before they set, a well-planned preventive propram will eliminate all skin or eye irrations, according to George Magurean, manager of Librascope's printed circuit processing operations.

After leaving the coating section, the circuit boards are baked at a maximum temperature of 150 F to harden the thermosetting epoxy. The temperature control is critical, since it is vital that the heat be adequate to cure the plastic without damaging the performance of the delicate electronic components. Masking tape, which is used to keep contacts and terminals free from the plastic coating, is removed after the boards leave the ovens.

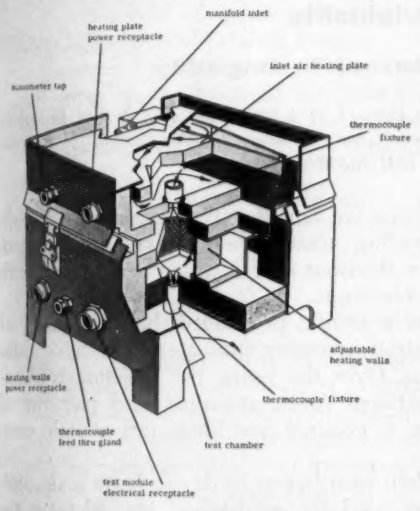
Potting operation protects "stacks" of two or more circuit boards. These are assemblies with boards joined in parallel forming an open-sided box-like construction, with electronic components on both the inside and outside of the box. The parts on the inside are protected by filling the space with plastic. Epoxy is also used in the potting, with special fillers added to provide maximum heat dissipation. The boards are placed in jigs and the liquid plastic resin poured in. The assemblies are then oven cured in the same manner as the coated boards, and the jigs removed.

Use of such protective measures is new in the computer field, according to Mr. Magurean, but will be used more extensively since computers are gaining recognition in on-line process control, portable field operations and in mobile installations. • • •

HEAT TRANSFER TESTING

Accurate Measurements with Simple Device

With a test fixture developed by Melpar, Inc., Falls Church, Va., design engineers can determine the effectiveness of any heat transfer design prior to the establishment of final design criteria. The heat transfer test fixture, Model T-400, accurately measures the heat transfer rate from an electronic module to a cooling air stream in a well defined temperature environment surrounding the module. The device which meets Mil-E-19600A(Wep) requirements, also provides a means for determining cooling air pressure drop across the module.



The fixture is divided into three chambers: the inlet air plenum, the outlet air plenum and the test chamber. The test area is closed by heated walls which can be physically arranged to accommodate modules of various sizes. Temperatures of selected module parts and frame members are monitored by attaching thermocouple junctions to the desired points. The manometer tap, thermocouple leads, and electrical leads are brought out through packing glands.

Various test, power and air connectors are easily accessible. The fixture will condition 0.4 lbs. of dry inlet air per minute over a temperature range of −20 to 70 C. The maximum input power ac or dc is 900 watts.

The device tests any forced air cooled electronic module having dimensions up to 9" wide x 4½" high; simulates temperature environment surrounding the module; permits checking of an air-cooled module with a minimum of expensive and elaborate equipment; and provides data for determining amount of air needed to sufficiently cool modules under a given set of environmental conditions.

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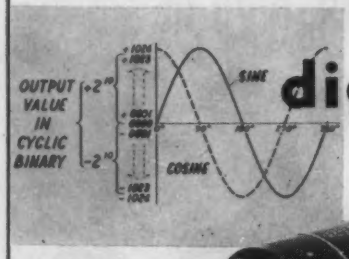

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CIRCLE NO. 46 ON INQUIRY CARD

STAFF COLUMNIST

Hyman Olken

LAWRENCE RADIATION LABORATORY
University of California
Livermore, California

The Art of Originality

Barriers to Originality

This column begins Part II of a series on The Art of Industrial Inventing. Part I, on Characteristics of the Inventing Process, was concluded in last month's issue.

In an earlier column we said that the process of originality consists of detecting what is being taken for granted, challenging it, then devising new ideas in accordance with the results of that challenge.

This sounds like a simple procedure, but the rarity of originality in industrial inventing indicates some basic difficulty in the process. Over the years, the inventor accumulates many conventional ideas, concepts and patterns of thought which tend to channel new ideas and exclude creativity.

For example, when men began to devise large scale digital computers, they used the established idea element for rapidly changing combinations of electrical circuits–the electromagnetic relay. Thus the very first large scale digital computers, the Harvard-IBM Mark I, Mark II, and the Bell Laboratories' Models 3, 4, and 5, were all electromagnetic-relay machines. Even at that time, vacuum tubes were known to provide a thousand-fold faster operation. But it was generally believed that vacuum tubes were subject to high failure rates with the result that the long chain of tubes involved in each arithmetic operation would inevitably break down before the operation could be completed: hence it was thought that vacuum tube computers would be utterly impractical.

Eckert and Mauchly challenged this belief and went on to develop the first electronic digial computer, the Eniac, revolutionizing the field (See Electronic Digital Computers, Franz L. Alt, Academic Press, 1958, pp. 17-19).

Another good example of this barrier to originality is found in Rulings of the U.S. Supreme Court in Recent Patent Cases of American Tri-Ergon Corp., *Society of Motion Picture Engineers Journal*, Vol. 24, No. 6, June 1935, pp. 529-550. When talking pictures were first considered, the great problem in scanning the sound track was to get the film, which had to be stopped intermittently for projection of each picture frame, to move between frames at a constant speed, so as to avoid the disturbing pitch fluctuations which would result from even a very slight variation in speed. Numerous and elaborate inventions were contrived to solve this problem–speed control regulators with vacuum tubes, saturable core reactors, split field motors, and other devices previously used for speed control.

But despite these elaborate controls, the very light film

responded to even the slightest irregularities in the motion of the film driving mechanism and thus caused irritating defects in sound reproduction. The invention that provided the solution to the problem was the one which challenged the idea that speed control contraptions were necessary. The inventor simply wrapped a loop of film (after it was projected) around a heavy flywheel to stabilize and smooth the film's motion.

APPROACH TO ORIGINALITY

Unfortunately, the human brain has no built in mechanism to indicate something that is being taken for granted. The best approach to originality is to analyze our thinking. General books on creativity, a bevy of which have appeared in recent years (For example, see *Applied Imagination*, Alex F. Osborn. Chas. Scribner and Sons, N.Y., 1953, p. 280), suggest a number of challenging questions . . . . . : Can a better result be achieved by reversing what is being done? Would it be better if something were omitted? Can something be added to achieve the same result in a better way?

For the field of industrial inventing these questions are more appropriately stated thus:

Reversal Can better results be achieved by reversing or inverting: a, the relations between functional elements; b, the functional pattern; or c, the sequence of events?

Elimination Can a step or a functional element be eliminated?

Indirect vs Direct Would an indirect, more elaborate procedure work better than a simple, straight forward arrangement?

WORKING PRINCIPLES OF ORIGINALITY

Although these general approaches are helpful, they are not enough to develop the level of originality required for professional inventing. Fortunately, however, the history of industrial invention reveals a number of other such questions which apply specifically to inventing, and which are so effective and widely applicable as to constitute, in effect, "working principles" for stimulating originality in the solution of industrial invention problems. The professional inventor will, with experience, evolve some of these "working principles" for himself; but to help him to a good start, a number of the most outstanding of these principles will be developed in succeeding columns. • • •

WORTH FILING

SERVO COMPONENTS AND GYROS

56 page manual describes in detail the important technical aspects associated with servo components and their use in systems. The diagrams, charts, outlines, tables, schematics, definitions, and formulas provide a convenient reference when designing high performance servo systems.

54 page manual covers theoretical considerations of gyroscopic instruments and details the performance, application, construction and testing of such instruments as rate gyros, rate integrating gyros, rate switches, free gyros, vertical gyros, directional gyros, stable platforms and accelerometers. Diagrams, equations, charts, graphs and tables help to illustrate the topics discussed.

Source: Kearfott Division, General Precision, Inc.
Little Falls, N.J.

For your copy of Servo Components Manual:
Write No. 677 in Box on Inquiry Card

For your copy of Gyro Manual:
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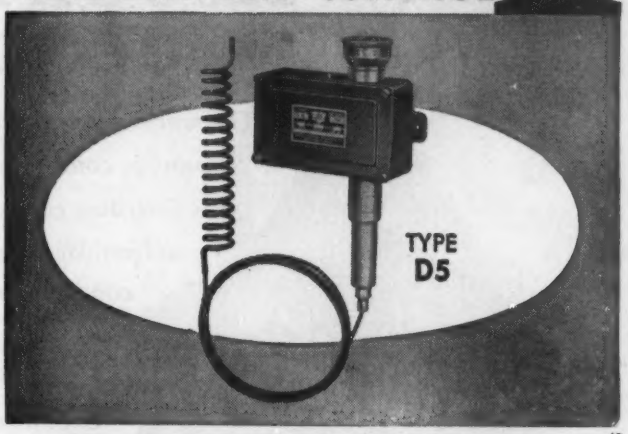
MICROMETER-ADJUSTED
REMOTE BULB TEMPERATURE CONTROL D5



UNITED ELECTRIC's Type D5 Remote Bulb Temperature Control is a precision unit containing a micrometer adjustment for obtaining wide ranges and accurate temperature settings. This control has found extensive use in applications such as laboratory and industrial ovens, water baths, hot plates, etc.

Temperature Ranges	−150°F. to +200°F., 70°F. to 370°F., 100°F. to 650°F.
Switch Ratings	15 amps at 115 or 230 volts AC. Also 20 amps or DC switches on specification.
Switch Types	N.O., N.C., or Double Throw — no neutral position.
On-Off Differential	Approximately 1.0°F. or 2.0°F. dependent on model.
Adjustment	Three-turn, calibrated knob rotated against graduated barrel. Readings and divisions equally spaced over entire range. Adjustment knob includes calibration screw.
Electrical Connections	Made to internally located terminal block via clearance hole in the enclosure.
Capillary Tube Length	Standard length six feet. Other lengths available.
Enclosure	Die-cast aluminum case with black wrinkle finish. Other finishes available.
Mounting	Control head surface mounted in any position by means of dog ears. May also be flush mounted.

UNITED ELECTRIC ***manufactures a complete line of temperature, pressure, and vacuum controls. Additional data on the Type D5 and other standard remote bulb temperature controls are contained in*** **Section 200** ***of our new catalog. Write for your copy now.***

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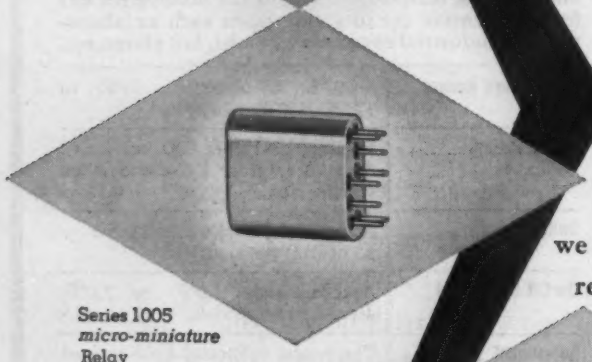
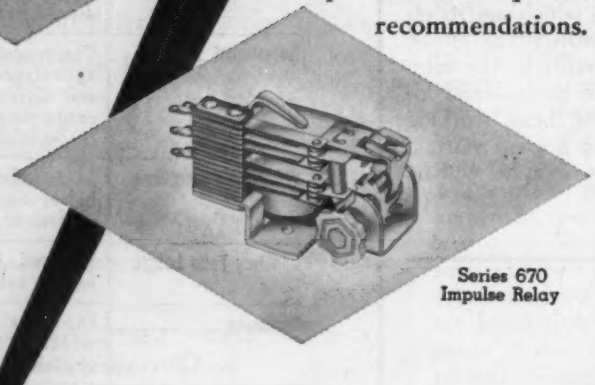
The world's most critical users of electromagnetic controls specify . . . Guardian. For Guardian relays, steppers, switches, solenoids, contactors and complete control assemblies traditionally express continuing progress in control engineering, creative design and highly reliable performance. To those whose responsibility it is to specify or buy the most applicable controls for industrial or defense production, we invite you—submit your requirements for specific recommendations.

P.E.R. Stepper electrical reset



Series 1005 *micro-miniature* Relay

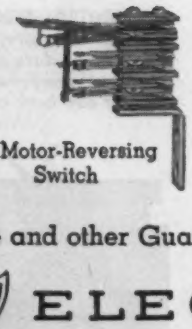


Series 670 Impulse Relay

RELAYS
SOLENOIDS
SWITCHES
STEPPERS
•
Complete Control Assemblies

No. 24 Solenoid

Series 1200 Midget Relay



Motor-Reversing Switch

Series 695-T Telephone Type Relay

Write for information on these and other Guardian Controls.

GUARDIAN ELECTRIC
MANUFACTURING COMPANY
1562-K W. CARROLL AVENUE, CHICAGO 7, ILLINOIS

CIRCLE NO. 44 ON INQUIRY CARD

WORTH FILING

Terminal Blocks and Switches

32 page catalog describes both terminal blocks and switches, giving complete mechanical and electrical information. Included are data on the latest plastic insulating materials, as well as the various terminal block configurations. Also described is a new insulating strip that provides extra breakdown dielectric strength between the terminal hardware and the chassis on which the terminal block is mounted.

Source: Kulka Electric Corp.
Mt. Vernon, N.Y.
For your copy: Write No. 609 on Inquiry Card

Thermocouple Assemblies

32 page catalog describes thermocouple fittings, pressure sealing glands, and thermocouple accessories. Included are bare wire thermocouple glands that provide low mass, fast response and simple positive method for sealing two or more bare wires from the full vacuum to 10,000 psi. at temperatures from —300 to 1850F.

Source: Conax Corp.
Buffalo, N.Y.
For your Copy: Write No. 578 on Inquiry Card

Variable Speed Drives

16 page catalog covers stopless variable speed drives for fractional horsepower applications. Operating features and installation suggestions are accompanied by numerous diagrams and tips on power transmission. Charts and diagrams answer virtually every question on use of mechanical variable speed.

Source: Zero-Max Co.
Minneapolis, Minn.
For your Copy: Write No. 580 on Inquiry Card

Coaxial Cables

40 page catalog provides complete information on coaxial cables as well as an up-to-date RG-/U nomenclature listing and electrical and mechanical information on cable materials and performance.

Source: Amphenol-Borg Electronic Corp.
Chicago, Ill.
For your copy: Write No. 601 on Inquiry Card

Circuit Testing

Manual describes methods for measuring insulation resistance, voltage breakdown and leakage current, as well as measuring electrical circuit grounds. Procedures and equipment described are particularly suited to the needs of maintaining transmission cables, power circuits, motors, generators and other equipment used in telephone, telegraph and signalling systems.

Source: Associated Research, Inc.
Chicago, Ill.
For your copy: Write No. 600 on Inquiry Card

WORTH FILING

Pulse Transformer

"The design and usage of miniature pulse transformers", a 20 page catalog, covers the history of low-level pulse transformers, other transformer types, methods of measurement, and theory of application. Data on pulse transformer equivalent circuits is also included, as well as information on transformer polarization and methods of degaussing a core.

Source: PCA Electronics
Sepulveda, Calif.

For Your Copy: Write No. 700 on Inquiry Card

Tantalum Capacitors

Latest technical information on wet-type tantalum capacitors is provided in a booklet containing specifications, performance characteristics, ratings, curves and application data. Described is a seal design that is said to be the best capacitor seal. Units cover range from 325 to 1.75 mfd with 6 to 125 max working voltages for operation at 85C at full ratings.

Source: Fansteel Metallurgical Corp
North Chicago, Ill.

For Your Copy: Write No. 701 on Inquiry Card

Vacuum Systems

Glass high vacuum systems catalog is said to be the first devoted exclusively to standard and custom built glass vacuum systems. Catalog contains a complete description of parts and accessory items and information on installation and application of these systems.

Source: Delmar Scientific Labs
Chicago, Ill.

For Your Copy: Write No. 703 on Inquiry Card

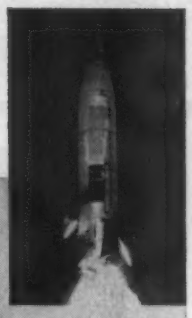
Digital Logic

72 page booklet, "Proceedings of the first users' conference on dynamic digital logic" includes the following: application of digital techniques in a meteor burst communication system; generation of periodic pulse patterns; a method of running off a quotient to the nearest integer; logical design simulation techniques; serial techniques in digital systems; serial techniques in the design of an incremental computer. Also reported are new and interesting applications of transistorized dynamic digital circuitry, their versatility and future possibilities.

Source: Computer Control Co., Inc.
Framingham, Mass.

For your Copy: Write No. 704 on Inquiry Card

FLOATED RATE INTEGRATING GYROS



Specifically designed for missile applications, these Kearfott miniature gyros are available with short term drift rates of 0.01°/hr. Their outstanding accuracy and performance make them superior to any comparably-sized units on the market. Wide angle displacement gyros with high torquing rates for "strap-down" applications are also being produced. Performance characteristics that are even more precise can be provided within the same dimensions.

KEARFOTT DIVISION
Little Falls, New Jersey

GENERAL PRECISION, INC.
Other Divisions: GPL, Librascope, Link

CIRCLE NO. 48 ON INQUIRY CARD

ELGIN ADVANCE RELAYS

HERMETICALLY SEALED* MILITARY DC RELAYS AVAILABLE FROM STOCK

SERIES	MV Crystal Can Size	VGS Miniature Sensitive Rotary	VG Miniature Rotary	MGA Printed Circuit Crystal Can Size	NM Subminiature Transistor Can Size	SD Miniature Sensitive
CONTACT ARRANGEMENT	DPDT (2 form C)	DPDT (2 form C)	DPDT (2 form C)	DPDT (2 form C)	SPDT (1 form C)	SPDT (1 form C)
RESISTIVE CONTACT RATING (AMPS)	2	5	5	2	0.25	1.5
COIL** RESISTANCE RANGE (OHMS)	30-7000	120, 500, 2000	25, 100, 500	35-9100	50-2000	1000-10,000
OPERATING POWER AT 25°C (MW)	250	100	340	250	100	40
DIMENSIONS (IN.)	0.875x 0.797x 0.359	1.125x 0.875x 0.875	1.125x 0.875x 0.875	0.875x 0.800x 0.396	0.530x 0.392x 0.196	1.786x 1.515x 1.515
WEIGHT (OZ.)	0.5	1.5	1.5	0.6	0.09	4.0

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NEW! 16 page CATALOG FREE!

* EVACUATED AT 2.5 INCHES HG ABS
DEGASSED AT 10 MICRONS AND 135-170°C
FILLED WITH DRY NITROGEN
RADIFLO LEAK TESTED UPON REQUEST

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ELGIN NATIONAL WATCH COMPANY
ELECTRONICS DIVISION • 2435 NORTH NAOMI STREET • BURBANK • CALIFORNIA

CIRCLE NO. 47 ON INQUIRY CARD

Service-Seasoned
Available Now

SOLID-STATE A-C
SERVO AMPLIFIER

Designed specifically for use in 115 volt, 400 cycle systems, this United Control servo amplifier drives standard Size 11, 40-volt center-tapped servo motors. Its performance has been proved in service on a high-performance military aircraft, and it is qualified to applicable portions of MIL-E-005272B. Transients on power input leads up to 190 volts for 100 milliseconds will not damage the unit. Gain stability of ±2 db is maintained over an operating temperature range of −55°C to +102°C. Now in production, your requirements can be scheduled for early delivery. Firm prices reflect manufacturing efficiencies gained from experience.

CHARACTERISTICS

Input Impedance: 10,000 ohms
Voltage Gain: 1,200 min.
Power Consumption: 0.65 va to 5.5 va
Max. signal Input: 45 volts
Size: 2.06" x 1.81" x 2.25"
Weight: .63 lb. max.

Write for technical bulletin and prices.

UNITED CONTROL CORPORATION

4540 Union Bay Place • Seattle 5, Wash.

CIRCLE NO. 49 ON INQUIRY CARD

MATERIALS

FILM-FORMING DIELECTRIC

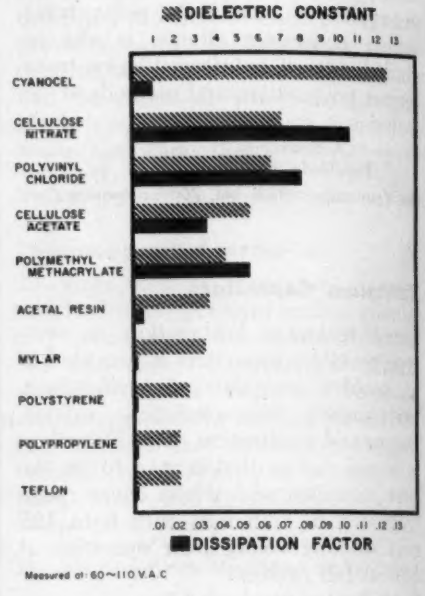
2-6 Times Greater Capacitance Per Unit Volume

Cyanocel, a chemically modified cellulose, is expected to find wide use in the micro-miniaturization of electrical and electronic parts. Developed by the American Cyanamid Co., New York City, N.Y., Cyanocel is made by treating a purified form of fibrous cellulose with acrylonitrile which is the same highly reactive chemical that serves as the basis for synthetic rubber, plastics and acrylic fiber.

Because of its high dielectric constant and low dissipation factor, Cyanocel, according to the company, provides a capacitance per unit volume two to six times greater than that of other comparable materials. The new dielectric has already found applications in electroluminescence and microminiature capacitors.

Clear, transparent films as thin as 0.1 mil or as thick as 5 mils or more have been cast from solutions of Cyanocel in a number of organic solvents or solvent mixtures. At a frequency of 60 cycles, 2-mil films have a dielectric constant of 10-15 and a dissipation factor of 0.010-0.025. Films of Cyanocel have good flexibility and physical strength; at 23 C and 50% relative humidity, 2-mil films have a tensile strength of 5380 psi and a Young's modulus of 0.34 x 10^6 psi.

Mechanical properties of the films can be changed by incorporating plasticizers. To prevent altering the electrical properties of the films, the plasticizers also should have high dielectric constants and low dissipation factors.



Measured at 60~110 V.A.C

Films of Cyanocel can be cast onto any flat, smooth surface, such as glass or metal foil. The glass or glass-fiber supported film is important in electroluminescence. The combination of metal foil with the new dielectric is advantageous to capacitor applications. In electroluminescence, Cyanocel acts as a carrier or binder for phosphor. As a carrier, it is the filling in a sandwich of two conducting plates, one of which is transparent. American Cyanamid Co., New York, N.Y.

Write No. 218 in Box on Inquiry Card

Bonding Aid

A sodium solution called Chem-Etch chemically corrects the surface of Teflon or other fluorocarbon resins so that adhesives will adhere to it with a high bond strength. The part to be treated is immersed in Chem-Etch from 5 to 60 seconds. After this application Teflon can be bonded to itself, metals, plastics, glass, ceramics or wood with various adhesives. A variety of adhesives can be used including chlorinated rubber types, resorcinol formaldehyde cements, as well as epoxies. Chemgineers, Inc., Los Angeles, Calif.

Write No. 501 in Box on Inquiry Card

Insulating Tubes

For use in a wide variety of insulating and encasing applications, metalized ceramic tubes are available in either steatite or high alumina, have inner diameters from 0.105" to 0.300", outer diameters from 0.156" to 0.395", and lengths ranging from 0.250" to 2.250". The tubes are metalized with a eutectic solder with a melting point of 183 C. Service temperature varies depending on the application. However, most high alumina tubes meet mil specs for thermal cycling from −65 to 125 C. Centralab, Milwaukee, Wis.

Write No. 616 in Box on Inquiry Card

Ceramic Printed Circuits

Perfection of large ceramic pieces that can serve as circuit boards is said to be a major breakthrough in bringing environmental specifications of printed circuits on a par with other electronic components and equipment. The high alumina bodies and moly-manganese circuits screened on, can be subjected to temperatures up to 1800 F without failure and will withstand equally exacting humidity and corrosive environments. The printed circuits are composed of high alumina bases (96%) and metal circuits which are a composition of molybdenum and manganese. The circuit is then protected with an electroplated coating of nickel or copper which serves as a base for hard or soft solder assembly techniques. Pattern configurations can be screened on to within ±0.005" and, on smaller sizes, tolerances of ±0.001" for hole centers can be achieved. Mitronics Inc., Hillside, N.J.

Write No. 524 in Box on Inquiry Card

Hermetic Sealing Beads

Multiform glass beads are available in a variety of shapes for both Kovar and compression type hermetic seals. Beads vary in size from 0.050" o.d. to 0.750" o.d., with thicknesses between 0.020" and 0.250" maximum. Electronic-Ceramics Co., Belleville, N.J.

Write No. 522 in Box on Inquiry Card

Hi-Strength Nickel Steel

Nominally identified as 25 percent nickel steels, alloys achieve unique properties by simply air cooling from the heat treating temperatures. Yield strengths in excess of 250,000 psi with 6 to 10% elongation and above 20 percent reduction of area are obtainable in section thicknesses where such high strength properties were not heretofore attained. In some cases yield strengths in excess of 290,000 psi have been achieved. Maximum hardness in excess of 67 Rockwell C has been obtained. The fact that the high strength properties are obtained without liquid quenching means that intricate parts can be fabricated to close tolerances while the steel is in its soft annealed condition and can be hardened to these high strength levels without appreciable distortion. International Nickel Co., N. Y., N. Y.

Write No. 504 on Inquiry Card

MAXIMUM ERROR 20 SECONDS ARC

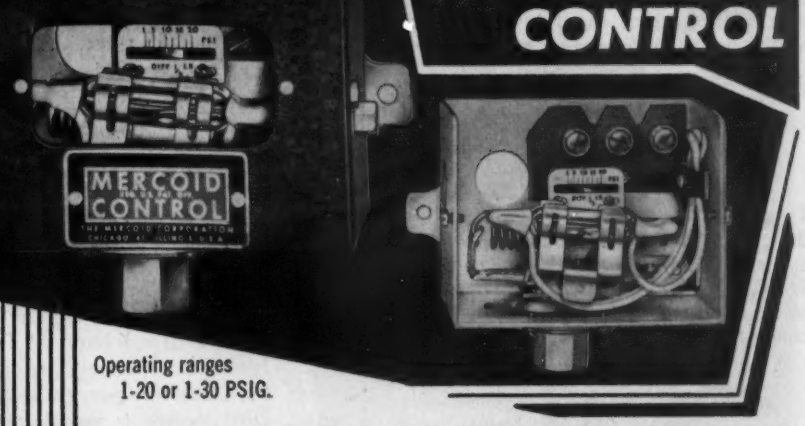
Available in both conventional and gimbal mounted configurations, these synchros provide component accuracies of 20 seconds of arc or better. They permit RMS accuracy for 3 unit strings of better than 0.75 minutes. Specifically designed for precise data transmission in missile-borne applications, these components eliminate the need for 2 speed servos and complex electronics, provide increased reliability and marked improvement in over-all system performance.

KEARFOTT DIVISION
Little Falls, New Jersey

GENERAL PRECISION, INC.
Other Divisions: GPL, Librascope, Link

CIRCLE NO. 51 ON INQUIRY CARD

Small, Lightweight
PRESSURE CONTROL



Operating ranges
1-20 or 1-30 PSIG.

TYPE AP-153 (STANDARD) PROVIDES SINGLE POLE CUT-IN, HIGH, SINGLE POLE CUT-IN LOW OR SINGLE POLE DOUBLE THROW OPERATION

GENERAL PURPOSE (NEMA 1): For indoor use or other general applications. Pressure element—Fairprene diaphragm. Pressure connection 1/4" I.P.S. Visible calibrated dial with pointer. External adjustment. Mounting—has two mounting ears (one on each side of control) or control may be pipe mounted by means of the 1/4" bottom connection. Wiring entrance—two 1/2" openings. Internal wiring connections. Hermetically sealed mercury switch with silicone rubber covered leads.

WRITE FOR BULLETIN 02

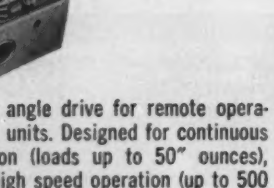
THE MERCOID CORPORATION
4201 Belmont Ave., Chicago 41, Ill.

CIRCLE NO. 50 ON INQUIRY CARD

NATIONAL
PRECISION
RIGHT ANGLE
AND
VERNIER DRIVES

Type PRAD: Right angle drive for remote operation of low torque units. Designed for continuous low-speed operation (loads up to 50″ ounces), and intermittent high speed operation (up to 500 RPM) with loads up to 100″ ounces. Less than 1½° backlash; drives and shafts of various lengths; various size output hubs; brass gears; stainless steel shafts, bushings and sleeves; die cast zinc housings.

Type RAD: Right angle drive. For ganging capacitors, potentiometers or other parts in heretofore inaccessible locations on chassis. Die cast zinc housing gears.



Type AN: Time-tested vernier mechanism. Designed for use with any 3/16″ National knobs and others. Drive ratio: 5 to 1; drive shafts: 3/16″, 1/4″ or to specifications; fully insulated output shaft coupling; output hub fits ¼″ shaft; readily adaptable to many types of drives.

Type AVD: Vernier mechanism. Similar to type AN (above) except that output-shaft is non-insulated. Dimensions: over-all diameter 2-9/16″, length 1-15/32″.

Write for new National Company components catalog! National Company, manufacturers of an extensive components line, invite inquiries for these and other electromechanical parts. For special components or a design or development problem, write:

National COMPANY
MALDEN 48, MASS.
SINCE 1914

CIRCLE NO. 52 ON INQUIRY CARD

COHERENT LIGHT SOURCE

Optical Maser Extends Radio Frequency Band Into Optical Range

The band of frequencies over which an electromagnetic energy source generates energy is often referred to in terms of its coherence—the smaller the band in which energy is radiated, the more coherent the source. Techniques of generating, amplifying, and detecting electromagnetic energy at higher frequencies for radar and communications applications depend essentially on the development of higher frequency coherent energy sources.

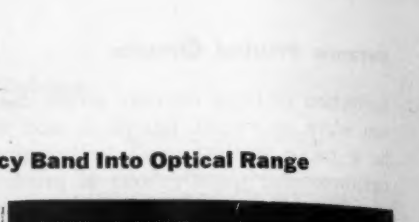
For years scientists have been seeking to project the radio spectrum into a range some ten thousand times higher by the development of a coherent light source. Now, culminating work by teams of scientists in many of the world's leading laboratories, Hughes Aircraft Company's research laboratories in Southern California have achieved this goal by the development of an "optical" maser, called appropriately, the laser. Hughes scientists say this new solid state device opens the way to many important achievements, including:

- True amplification of light.
- A scientific tool for investigating properties of matter.
- Focusing light into high-intensity beams for space communication.
- Vast increase in number of communications channels.

Stated briefly, the essential steps in the operation of the laser are:

A light source, in the form of a powerful flash tube lamp, irradiates a synthetic ruby crystal which absorbs energy over a broad band of frequencies. This optical energy excites the atoms to a higher energy state from which the energy is reradiated in a very narrow band of frequencies. The excited atoms are coupled to an optical resonator and stimulated to emit the radiation together.

As a direct consequence of its coherence the laser is a source of very high equivalent-temperature, higher than at the center of the sun. By equivalent temperature we mean the temperature to which an ordinary light source would need to be heated to generate a signal as bright as the laser's at the laser's color. Of course an ordinary light source would disintegrate before such heat could be achieved, but the laser being a "cool" source in the ordinary sense of the word, does not burn up.



Glowing with absorbed light is a synthetic ruby crystal (top), the "heart" of a new device called a laser (from Light Amplification by Stimulated Emission of Radiation) developed at the research laboratories of Hughes Aircraft Company. A light source (below) pours "random" waves of light into the ruby, exciting the gem's tightly-packed atoms. This stored energy then reradiates light in sharp beam.

Color of light is a manifestation of its frequency, and the purity of a color is determined by the width of the emitted spectrum. Since lasers can produce light waves a million times more monochromatic, or single hued, than those from a mercury or neon lamp, lasers can generate the purest colors known. This is one more way to describe the coherence of the laser.

Another important property of a laser, indirectly a consequence of its coherence, is that it radiates an almost perfect parallel beam. It could, in principle, generate a beam less than a hundredth of a degree of arc wide which when reaching the moon, for example, nearly a quarter of a million miles away would illuminate a lunar area less than 10 miles wide. By contrast, if an ordinary searchlight could reach the moon, its beam would spread over 25,000 miles and its brightness would be correspondingly reduced. As another example, the laser beam if sent from Los Angeles to San Francisco would only spread 100 feet, whereas the

searchlight beam would spread 50 miles.

The laser's use in radar and communications for space work is obvious, since there is no atmosphere in space to absorb or scatter the beams. It could be used in effect as a light radar. The small beam spreading would give rise to extremely high resolution making it possible to take detailed pictures with a clarity never before attainable. A beam directed at the earth from a satellite 1,000 miles up would be concentrated into an area about 200 feet wide.

Write No. 215 in Box on Inquiry Card

CERAMIC FIBERS-TO-METAL

Bond Withstands Very High Temperatures

Development of a unique metallurgical process which combines ceramic fibers with metal to attain extremely high strengths was announced by Horizons Incorporated, Cleveland, Ohio. While emphasizing that the technique is still in the experimental stage, Dr. Eugene Wainer, Vice President and Director of Research, called the results a "major scientific breakthrough" and a potential solution to problems in applications where ultra-high temperature resistance is required.

The search for an ideal combination of metal and fibers required an examination of countless alloys and ceramic materials. Research indicated that, to be acceptable, the metal had to exhibit no precipitation phases resulting from alloy combination or heat treating and had to maintain substantial oxidation resistance to the melting point.

Selection of a fibrous material imposed similar strict requirements. Horizons Inc. determined that the inorganic fiber must have:

- density less than that of the metal in question
- melting point very much higher than the metal matrix
- coefficient of expansion equal to or less than that of the metal
- elastic tension modulus greater than that of the metal
- strength very much greater than the metal

According to Dr. Wainer, an alloy which comes close to meeting the metal specifications is an 80% nickel–20% chromium composition; and the inorganic fiber best suited for incorporation is an aluminum oxide of sapphire or corundum single-crystal form. The tough ceramic fibers can be wrapped around a radius of a fraction of an inch without fracture. About half of the fibers' high tensile strength is retained at the melting point of the nickel-chrome alloy. • • •

Highly precise and accurate, Kearfott two-axis accelerometers are pendulous devices which sense airframe acceleration forces acting on them.
An inverted pendulum utilizing a unique Hooke's joint suspension displaces as a function of acceleration in either of 2 axes. An AC pickoff signal is rectified and applied to voice coils restoring the pendulum to null. The DC required for restoration is proportional to acceleration. Typical characteristics for these units include range of ± 25 g's, scale factor of 5.0 ma/g, linearity of ± 0.005% and threshold of 2 x 10^{-7} g's.

KEARFOTT DIVISION
Little Falls, New Jersey

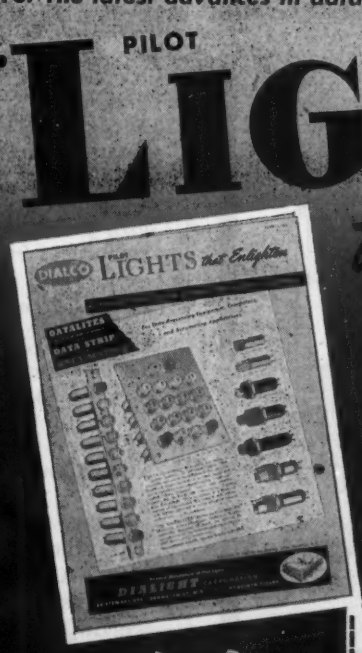
GENERAL PRECISION, INC.
Other Divisions: GPL.Librascope. Link

CIRCLE NO. 54 ON INQUIRY CARD

For the latest advances in data illumination, read:

"PILOT LIGHTS that Enlighten"

by DIALCO



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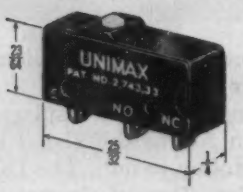
Address_____
City_____ Zone____ State_____

CIRCLE NO. 53 ON INQUIRY CARD

SEALED subminiature precision SWITCH
resists CORROSIVE ATMOSPHERES

LIFE-TESTED in a wide variety of highly corrosive atmospheres, the UNIMAX Type SS has proved that its construction effectively seals out fumes and gases, to assure dependable operation even after long exposures.



- Mounting and outline dimensions meet MS-25085-1.
- Available with auxiliary actuators.
- Electrical rating: 5 amp. 125, 250 volts a-c, Underwriters' Laboratories listed.
- Groups of these Type SS sealed switches combined with special actuating devices can be furnished to your requirements.

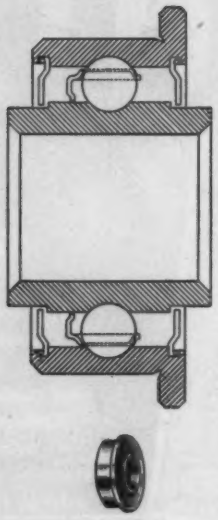
Write for complete information.

UNIMAX SWITCH
Division, The W. L. Maxson Corporation
IVES ROAD, WALLINGFORD, CONNECTICUT

CIRCLE NO. 55 ON INQUIRY CARD

Now — do away with bosses!

Being revolutionary is routine with MPB miniature bearings. Used in gear trains, MPB extended inner ring bearings eliminate gears with bosses. For details about extended inner ring bearings — or any of MPB's 500 types and sizes — write to MPB, Inc., 129 Precision Park, Keene, N.H.



MINIATURE PRECISION BEARINGS INC.

MPB
Helps you perform miracles in miniaturization

CIRCLE NO. 56 ON INQUIRY CARD

WORTH FILING

Special Shaped Wire

16 page catalog describes various wires that are preshaped to a desired cross-section. Also contained is information on methods of calculating areas of common shapes; physical properties of steel wire; table of standard wire gauges; and hardness conversion tables.

Source: American Chain & Cable Co., Inc.
Bridgeport, Conn.

For your copy: Write No. 662 in Box on Inquiry Card

Air Control Valves

40 page specification catalog covers inline 2, 3, 4 way valves and sub-base mounted 4 way and 4 way 5 port valves. Valves are air operated or solenoid pilot operated and have solenoid pilot and booster and double solenoid pilot. Valve selection tables and parts tables, information on installation and maintenance, and on conversion of valves to external pilot supply, are included.

Source: The Hoffman-Odom Co.
Dayton, Ohio

For your copy: Write No. 664 in Box on Inquiry Card

Batteries

Ten page brochure describes the physical, electrical, and typical application types: high-rate for complete discharge in less than an hour and low-rate for discharge rates longer than an hour. The rugged batteries are said to provide reliable high energy output per unit of weight and size and level voltage throughout discharge.

Source: Yardney Electric Corp.
New York, N. Y.

For your copy: Write No. 663 in Box on Inquiry Card

Hose Fittings

12 page specifications catalog contains data on re-usable low pressure hose couplings, union swivel adapters, hose assemblies in 1 and 2 rayon braid with re-usable couplings, oxygen and acetylene couplings and connectors, paint spray air hose couplings and connections and other fittings.

Source: The Lenz Co.
Dayton, Ohio

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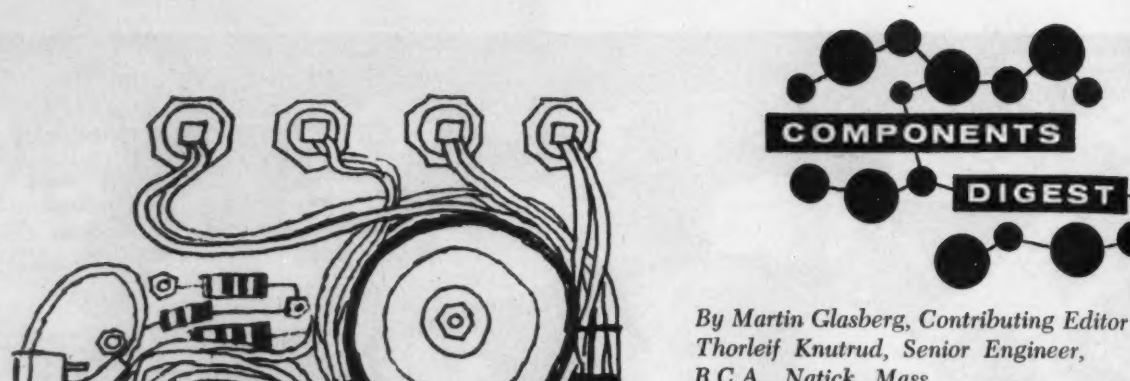


COMPONENTS DIGEST II

By Martin Glasberg, Contributing Editor and Thorleif Knutrud, Senior Engineer, R.C.A., Natick, Mass.

Audio Power Amplifiers

PART IIIB Magnetic Amplifiers (Continued)

REVIEW

Part A in the April 1960 issue of the Components Digest on Magnetic Amplifiers emphasized principles of magamp operation. The single most important point presented in the first part was that the core losses in a saturable reactor can be approximated by magnetizing resistance, R_M. This resistance was shown to stem from the old eddy current loss resistance associated with transformer equivalent circuits. Using R_M, equivalent circuits and block diagrams, we obtained the equations for dynamic performance for a whole series of circuits that span the spectrum of magnetic amplifiers—starting with the saturable reactor and positive feedback circuits and ending with the fast magamp circuits.

Certain basic ideas were presented in Part A. First, no inductance is present in a magamp and the output is incremental. If the incremental output is approximated as a smooth function at low frequency, a normal time constant appears to exist; but this time constant was shown to be due to delayed response and feedback and not inductance. Second, three feedback paths occur in the parallel connected saturable reactor circuit; negative feedback of the load current into the control circuit, positive feedback of the voltage across the gating core into the voltage across the resetting core, and negative feedback due to current flowing through R_M.

Part A went on to show that circuit advances could be described as merely the elimination of one or more of these feedback paths. Positive current feedback or blocking diodes in the gate circuit eliminate the load current feedback creating a self-saturating characteristic and an increase in gain. Positive feedback between the core voltages is eliminated with either diodes in the control circuit or by firing both cores during the same half cycle, obtaining fast response. In this section we continue our Digest with practical extensions of these findings.

This article first discusses the practical problems in using magamps. More specifically, six popular circuits are considered in detail. These circuits were chosen to cover a wide range of types but they are predominantly fast circuits that drive two phase servo motors.

Two problems are most generally encountered: distortion of the waveforms and heating of the cores. Table I contains complete Fourier analysis for the waveforms of the six circuits with resistive loads; the amplitude of the dc, the fundamental, the quadrature, the second harmonic and, in two cases, the third harmonic components are plotted as a function of the average input voltage. The heating problem is considered and a graph of approximate core size as a function of power dissipation is included.

A review of the various types of amplifiers rounds out the series on Audio Frequency Amplifiers. The review stresses the vacuum tube and thyratron amplifiers since they have not been considered in detail and emphasizes the potential growth of the silicon controlled rectifier amplifier—because they will undoubtedly play an important role in the future of audio frequency power amplifiers.

GENERAL PROBLEMS IN MAGNETIC AMPLIFIERS

In general, magamps can be expected to have certain common failings. First, as in any discontinuous amplifier, the output waveform is far from sinusoidal. Large and variable harmonic components can be expected as a function of the input signal and the bias voltage. This problem is clear-cut and its effect can be easily evaluated with resistive loads. If the load is slightly inductive, tuning (parallel capacitance in resonance with the inductance at the carrier frequency) may help by cutting down on the harmonic content without introducing too much dynamic phase shift.

Truly inductive loads, however, can be a bad problem because the voltage across the cores and diodes will not be in phase with the supply voltage. This condition produces considerable errors when compared with the analysis based on resistive loads. The problem is not completely black because the circuit can be reanalyzed using the actual inductive load. An analysis of this sort, however, is not too common and in most cases the resistive equivalent is satisfactory or is used anyway.

Saturable core characteristics present less exact problems. In Part I we showed that the amplifier's input-output curve, using R_M, reasonably approximated the actual curve. In a later section of this part, R_M is introduced as a measured function of the core characteristics. These characteristics, however, are dependent upon frequency and temperature. Thus temperature or power supply frequency variations can produce inaccuracies in the analysis and a drift in the input-output characteristics of the amplifier.

Drift can also be produced by the load impedance, supply voltage and diode characteristic changes. In our analysis diodes were considered ideal and, of course, this is far from the case. Diodes will leak producing a recurrence of the load current negative feedback effect. Even if we took this leakage into account in the analysis or made experimental corrections to the analysis, we could expect drift resulting from variations in the diodes. This phenomenon is especially true of semiconductor diodes whose characteristics are noted for their sensitivity to temperature. The power supply voltage and load impedance have already been considered in the analysis so that their affect upon dynamic performance is evident. Any changes in load or supply voltage either with age, temperature or just in a random fashion will, therefore, produce a drift in the amplifier characteristics.

A further complication is the need for biasing. Bias must be used in all self-saturating circuits to produce a phase sensitive output. Bias is just a second input, held at a constant level, generally to produce half the maximum output when the regular signal input is zero. The possibility of the bias circuit affecting the amplifier was completely neglected in the analysis. This assumption is quite good if the reflected impedance of the bias circuit is high. Reflected impedance means large series resistance and low turns on the cores. This high impedance condition is generally achieved but the parameters of the bias circuit and the bias voltage itself contribute to the amplifier drift.

After the foregoing discussion we are safe to say that, even though we present a fairly detailed analysis, the magnetic amplifier characteristics still remain slightly uncertain without the support of empirical data.

SAMPLE CIRCUITS

The following six cases were chosen as popular examples of the various magnetic amplifier circuits in use today. Table I contains a schematic for each circuit, the general dynamic parameters of each circuit, a sketch of its waveforms, a Fourier analysis of the waveforms (with a resistor load), and a series of remarks about its salient features and problem areas.

CASE I

This first circuit is mainly a building block for other fast magamp circuits. It is very similar to the first saturable reactor circuit considered in Part A. The only difference is a blocking diode in the gate circuit that eliminates the load current negative feedback as well as the core voltage feedback loop since there is only one core. Ramey showed, therefore, that only a pure delay can occur in this circuit, which with a diode in the control loop, carries his name. The diode in the control loop improves the control characteristic only slightly in this case but is critical in Case II.

The Fourier analysis shows that the harmonic content of the output waveshape is especially high. All the components under consideration were found. The dc component is large and increases linearly with the average input voltage. Quadrature and second harmonic components are also present to a strong degree. The fundamental component, however, does increase fairly linearly with the average input voltage.

CASE II

The second circuit, used quite frequently for small two phase instrument motors, can be described as a double Ramey circuit. This circuit was used as an example in Part A and described quite fully at that time. As a review, the input is ac and aids the bias in resetting one core, and on the next half cycle opposes the bias in resetting the other core. In this way the first core fires (saturates) early with respect to its zero signal firing point; the other core, on the next half-cycle, fires later. The two core control voltages can not interact because of the diode isolation.

The most important feature of this circuit is that it has an ac output even though current only flows in one direction through the load. The Fourier analysis explains this seeming inconsistency. The curves show that while the complete output current flows in one direction, it is composed of a fundamental component, a second harmonic, and a constant dc component. The dc component is only constant because we chose a quiescent (zero signal, bias controlled) firing at 90° of the carrier wave. If either a greater or smaller quiescent firing angle is used, the dc component will vary with the average input voltage.

The Fourier Components are the reason why a two phase motor is a likely load for the double Ramey circuit. First, the control impedance of the small two phase instrument servo motor is especially resistive. Second, the constant dc component acts to increase the damping coefficient, a desirable feature in fast instrument motors. Third, the fundamental component, which alone produces the output torque, is a linear function of the average input voltage. Last, any quadrature in the input signal is suppressed by the amplifier and the second harmonic component only acts to heat the motor.

CASE III

This circuit is a departure from the double Ramey circuit which attains fast response by isolating the gating core voltage from the resetting core voltage with diodes. This third circuit attains fast response by eliminating the resetting and gating feedback because both cores fire in the same half-cycle.

Case III was also used as an example in Part A and described quite fully at that time. As a review, the input

TABLE I. SIX POPULAR FAST MAGAMP CIRCUITS FOR DRIVING TWO-PHASE SERVO MOTORS

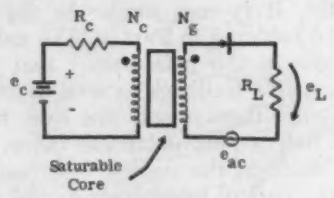
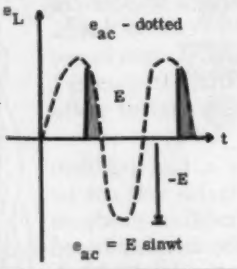
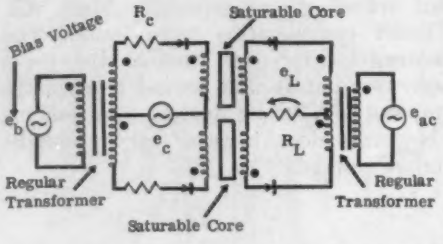
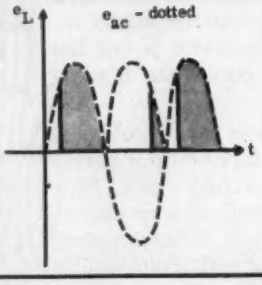
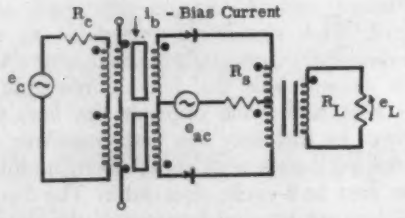
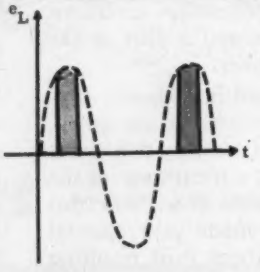
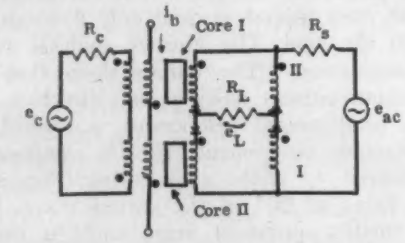
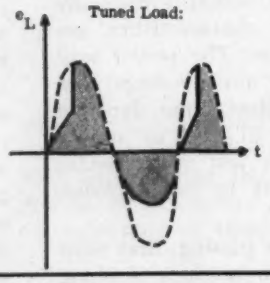
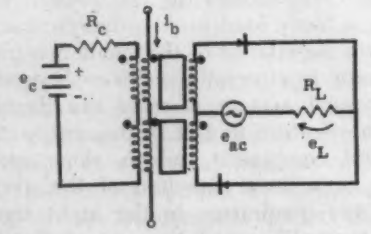
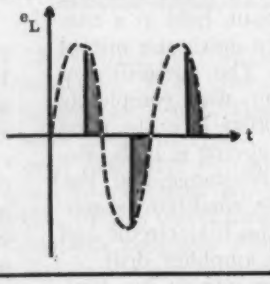
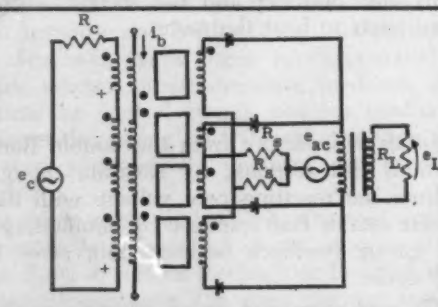
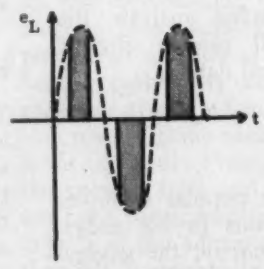
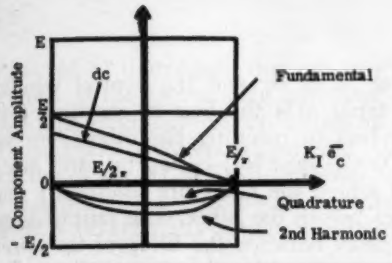
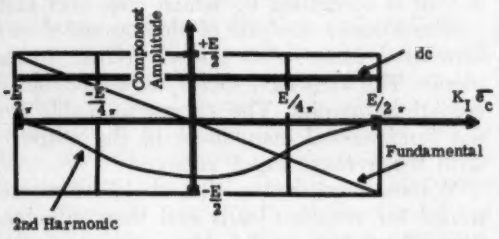
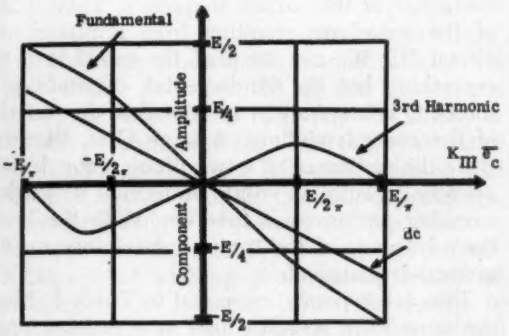
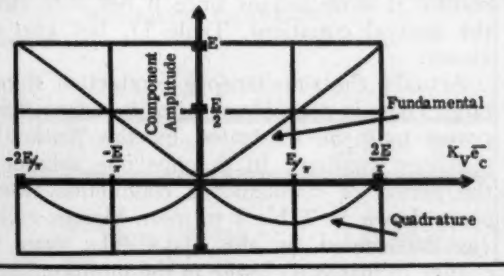
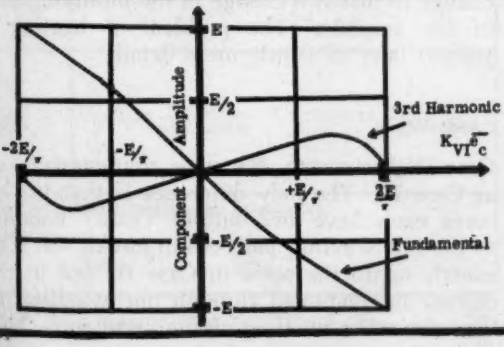
CASE NUMBER	NOMENCLATURE e_c = input voltage ; e_{ac} = supply voltage e_L = output voltage ; R_L = load resistance R_c = control resistance; R_s = limit resistance	WAVEFORMS	FORMULAS R_w = winding resistance; $R_w' = R_w + R_s$ R_M = magnetizing resistance A bar over a variable indicates average value
I			$\frac{\overline{e_L}(s)}{\overline{e_c}(s)} = K_I e^{-TS}$ $K_I = \frac{R_M N_g}{2(1+\frac{R_w}{R_L})(R_c + R_m) N_c}$ T=1/2 - 1 CYCLE OF SUPPLY FREQUENCY
II			The average voltage gain cannot be defined in this case, but the firing angle does follow the average input exactly as in case I. For the output as a function of the average input times the gain, K_I, see the Fourier Analysis. RESPONSE: 1/2 - 1 CYCLE DELAY
III			$\frac{\overline{e_L}(s)}{\overline{e_c}(s)} = K_{III} e^{-TS}$ $K_{III} = \frac{R_M N_g \cdot \alpha}{(1+\frac{R_w'}{R_L})(R_c + 2R_M) N_c}$ α = 1.0 FOR A RESIST. LOAD α = 2,3 FOR A TUNED LOAD $R_w' = R_w + R_s$ T = 1/2 - 1 CYCLE OF SUPPLY FREQUENCY
IV			
V			$\frac{\overline{e_L}(s)}{\overline{e_c}(s)} = \frac{K_V e^{-TS}}{\tau s + 1}$ $K_V = \frac{R_M N_g}{(1+\frac{R_w}{R_L})(N_c R_c)}$ For $R_c \ll R_M$ $\tau = \frac{\pi}{w} \frac{R_M}{R_c}$; T=1/2 - 1 CYCLE
VI	 Polarities: • a-c Control, + d-c Control	 (EMD Staff Artist)	$\overline{e}_L(s)/\overline{e}_c(s) = K_{VI} e^{-TS}/\tau s + 1$ DC CONTROL $K_{VI} = \frac{R_M N_g}{(1+\frac{R_w'}{R_L})(R_c + 4R_M) N_c}$ $\tau = \frac{\pi}{w} \frac{2R_M}{R_c}$; T = 1/2 CYCLE AC CONTROL $K_{VI} = \frac{R_M N_g}{(1+R_w'/2R_L)(R_c + 4R_M) N_c}$ $\tau \cong 0$; T ≅ 1/2 CYCLE

TABLE I. SIX POPULAR FAST MAGAMP CIRCUITS FOR DRIVING TWO-PHASE SERVO MOTORS (Continued)

FOURIER ANALYSIS Fourier analysis of waveforms with resistive loads-abscissa is the average input voltage, e_c, times the average voltage gain of the circuit, K_I for the case I example.	REMARKS
	• Usually called a Ramey Circuit when diode is in control circuit. • Half wave, non-reversible output. • For practical circuits R_M must be comparable to, or less than, R_c.
	• Called a double Ramey Circuit because of its dependence upon Case I. • Bias is adjusted by setting voltage e_b shown in the schematic. • Used mostly for small two phase servo motors because of constant D. C. component (when biased to quiescent firing angle of 90°) and linear fundamental component. • For practical circuits R_M must be comparable to, or less than, R_c.
	• Circuit may be controlled either a-c or d-c, it is sensitive to control only during one half cycle. • Power gain for resistive load from 100 to 500 watt/watt. • The proper value of R_s will depend upon the bias current, i_b, and the resulting quiescent firing angle. For a quiescent firing angle of 90°, R_s should equal R_L in case IV, and $n^2 R_L$ 4 (n is the turns ratio of the output transformer) in Case III. With larger firing angles R_s can be made smaller, but the limit should be the case where the dissipation at max. output equals to or is larger than the quiescent dissipation. • The load may be tuned resulting in the waveform sketched. Tuning the load for carrier frequencies below 400 cps produces only negligible reduction of harmonics. • Note that a reactive load alters the gain. • The bias resistance or source resistance of i_b should be larger than R_c to neglect it. • The dissipation in R_s makes efficiency no better than 50%.
	• This circuit is usually called a Doubler or "Amplistate" and is basically an outgrowth of saturable reactor amplifiers. • A time constant of several minutes can be obtained by using a small value for R_c and increasing R_M by increasing N_c, the number of turns on the control winding. • In general, a large value of R_M is used to obtain large gain with the attendent large time constant. See section on Magnetizing Resistance for a discussion of how R_M is measured. • The circuit in this case gives a full wave, non-reversible output. For a reversible output two identical circuits are needed. • The ratio of power gain to time constant can only be improved by reducing the core size, improving the winding space factor or increasing the carrier frequency. • The efficiency of this circuit is high since no series limiting resistor, R_s, is needed.
	• This circuit may be controlled either ac or dc, but each type of control will give different characteristics due to the necessary reversal of the control windings. • For dc control R_M may be made large compared to R_c. • For ac control the optimum value of R_M is $R_c/2$. • For ac control same as 3rd comment in Case I. • For ac control same as second comment in Case III. • For both types of control same as 3rd comment in Case III. • For dc control same as 2nd comment in Case V. (EMD Staff Artist)

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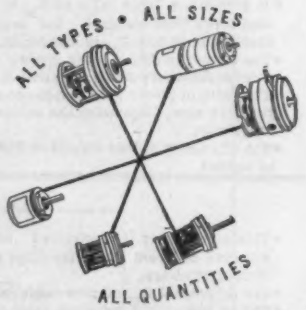

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can be either ac or dc and the control windings are set so that the input aids the bias in resetting one core and opposes the bias in resetting the other core in the same half-cycle. On the next half-cycle, the reset flux determines the point at which the cores fire (saturate) and therefore one core fires before the other. The output is proportional to the time delay between the firing of the cores and, consequently, proportional to the input. The polarity of the output is controlled by which core fires first.

The Fourier analysis of this circuit shows that the only unwanted components are a variable dc and a third harmonic. The amplifier, therefore, suppresses quadrature and second harmonics. The curves in Table I also show that the fundamental component in the output is fairly linear with the average input voltage.

We must remember that the Fourier analysis is determined for resistive loads and that inductance in the load will affect the results. One scheme for eliminating the effect of the inductance in the control winding of a two phase motor depends upon a parallel capacitance to "tune out" the reactive component of the impedance. This tuning is achieved by choosing the capacitance such as to attain resonance at the carrier frequency. Table I shows a sketch of the waveform resulting from a tuning capacitance on circuit III. We can see that the tuned load tends to reject everything but the fundamental, depending, of course, on the Q. Q is inversely proportional to the resistive component of the control winding. A large Q is, therefore, not likely since the resistance of a two phase motor is fairly large and, anyway, a large Q would introduce dynamic lag into the amplifier performance function. With the low Q, however, the advantage of the tuning capacitance for 60 cps. carrier systems is marginal.

Two other points are noted in Table I. First, gain is not the same for a resistive load as it is for a tuned load. Second, a series resistor, R_s, must be used to limit the current during simultaneous conduction. The increased gain for tuned loads is reasonable since it appears as a trade-off against the added dynamic lag. The need for a limiting resistor is more serious since it not only affects gain (see the general equations, Table I), but also decreases efficiency.

Actually the simultaneous conduction through two saturated cores is a problem, since it means that considerable power must be dissipated by the limiting resistors and the core windings. In practice one solution is to reduce the period of simultaneous conduction from the quarter cycle shown in Table I to more like an eighth of a cycle (as determined by the bias). The main effect of the change in bias is a change in the input-output characteristic of the amplifier. The problem of heating will be considered later in a little more detail.

CASE IV

Case IV has exactly the same characteristics and problems as Case III. The only difference is that in this circuit two cores each have two output (gate) windings compared to the one winding per core in circuit III. These cores fire exactly as do the cores in Case III but in this circuit the current is conducted through one winding, the load, and then the other winding of the same core. The load, there-

fore, is connected to the supply through two windings on a saturated core. If the second core now fires, it shorts out the first core and simultaneous conduction is experienced.

The only practical differences between Case III and Case IV are that Case III has simpler cores, uses two less diodes and requires either a split load, a centertaped autotransformer or a centertaped output transformer.

CASE V

This circuit is a simple half-wave doubler or "amplistate." In Part A we showed that this circuit was an outgrowth of a parallel connected saturable reactor circuit where the gate diodes blocked the load current negative feedback. It has more gain than a saturable reactor circuit but is much slower than the other circuits shown in Table I.

The Fourier analysis shows that the fundamental component of the output in this case is a linear function of the average input voltage. Reversing a two phase motor requires a full wave doubler; the full wave circuit is just double the half wave circuit. The only problem in the full wave circuit is that biasing is more difficult and simultaneous conduction will occur.

CASE VI

The last case is the most sophisticated circuit shown. Its operation is very similar to circuit III in that the output is determined by the time delay between the firing of parallel cores. This circuit, however, has twice as many cores as circuit III and produces a full wave output. The problem in this case is that with all the control windings, isolation between the gating core voltage and the resetting core voltage can not be achieved. There is always a feedback between the control winding of the gating cores and the control winding of the resetting cores. The results of this feedback depend upon the polarities of the control windings which depends upon whether the input is ac or dc. Table I notes the various effects of the voltage feedback upon the dynamic parameters of the circuit.

THE MAGNETIZING RESISTANCE

$$R_m = 2\left[\frac{dB}{dH}\right]\frac{A}{L} f N_c^2$$

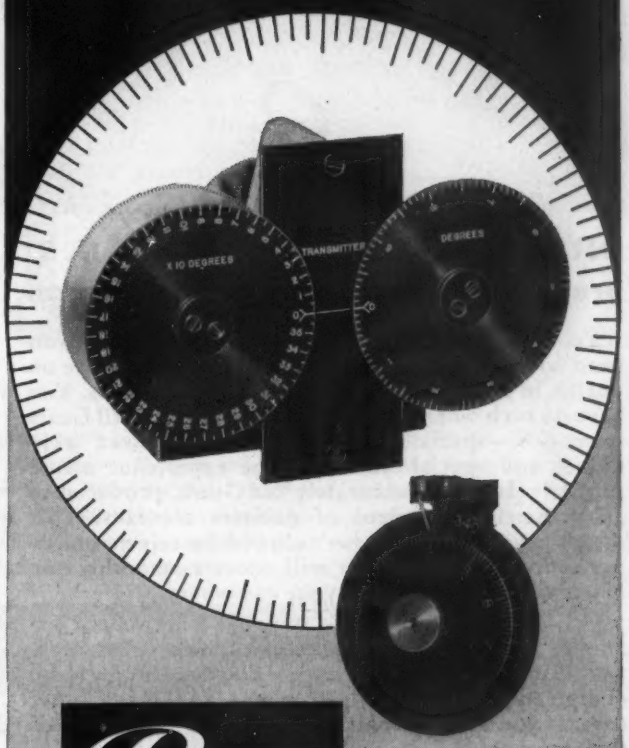
CORE MATERIAL TRADE NAME	$\frac{dB}{dH}$ at 60 $\frac{cycles}{sec.}$	$\frac{dB}{dH}$ at 400 $\frac{cycles}{sec.}$
ORTHANOL ORTHONIC DELTAMAX HIPERNIC V	0.32 $\frac{volt\text{-}sec.}{amp.\text{-}meter}$	0.65 $\frac{volt\text{-}sec.}{amp.\text{-}meter}$
4-79 PERMALLOY MO-PERMALLOY D-HY-MY-80	0.25 $\frac{volt\text{-}sec.}{amp.\text{-}meter}$	0.57 $\frac{volt\text{-}sec.}{amp.\text{-}meter}$

Empirical founder for interpolating to other frequencies:

$$\left[\frac{dB}{dH}\right]_f \cong \left(\frac{f_o}{f}\right)^{0.4}\left[\frac{dB}{dH}\right]_{f_o}$$

Fig. 1 The Magnetizing Resistance, R_M.

READOUT Reliability



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COMPONENTS DIGEST

MAGNETIZING RESISTANCE

In Part A we arrived at the magnetizing resistance, R_M, by approximating the square loop hysteresis characteristic of a saturable reactor with an elliptical characteristic. Figure 1 shows the mathematical relationship resulting from this approximation. B is the magnetic flux density, H the magnetizing force, L is effective magnetic path length, A is effective cross-section, f is carrier frequency and N_c is number of turns on the control winding.

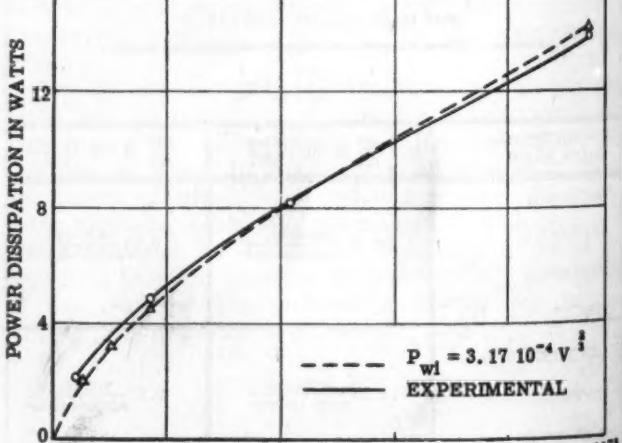
Figure 1 also includes a short table of approximate values for dB/dH (the change in flux density for a small change in magnetizing force) as a function of carrier frequency and core material. The empirical formula permits extrapolating dB/dH to other frequencies.

HEATING

In the discussion of the six magnetic circuits, we brought up the problem of heating many times, especially in connection with simultaneous conduction through two parallel saturated cores. When power is supplied to the load, the heating in the amplifier is relieved because current is conducted through the high load impedance in series with the saturated core windings and the limiting resistor, R_s. At times (simultaneous conduction) one saturated core shorts out the other saturated core, placing the two cores in series with a limiting resistor and the supply. During these intervals large currents will flow, heating the limiting resistor and the cores.

Here is where magnetic amplifier design gets to be a real problem. The designer must juggle the quiescent firing angle (and consequently the input-output curve), the supply voltage, the limiting resistor, the core size and characteristics, the resistance in the windings, and a great many other factors to come up with a practical design.

Lately analogue computer programs have been set-up to solve the resulting simultaneous equations. ELECTROMECHANICAL DESIGN carried a very interesting article on



Servomechanisms Laboratory, MIT Technical Memorandum No. 36, June 15, 1956

Fig. 2 Power dissipation in Magnetic Core at temperature difference of (100-25)° vs. core volume.

this subject in the Dec., 1959 issue, pages 36 to 41. Our purpose here is not as comprehensive, but we can get some idea of the problem from Figure 2. A curve is drawn for a convection cooled core; the heat input is based upon the average power dissipated in the winding (i^2R). The heat absorbed by the air is based only upon the core colume and not its shape. Any time the operating point lies above the curve, the core will attain a temperature in excess of 100 C. If the air temperature is above 25 C the curve must be lowered. This curve does not make any mention of the cooking which the limiting resistor is being given.

SUMMARY COMMENTS

We have discussed Audio Frequency Power Amplifiers in several Component's Digests. A general discussion of vacuum tube, transistor, thyratron, and magnetic amplifiers was first presented. Transistor amplifiers and magnetic amplifiers were then considered in some detail. We skipped the detailed discussion of vacuum tube and thyratron amplifiers for a number of reasons. Vacuum tube amplifiers are in great supply and their principles are well known. Thyratron amplifiers, although they have been used lately in some very interesting ways, are still only presented in commercial units of especially high power. The key to our selections were reader needs and interest, and the availability of commercial packages. This last point was one reason why silicon controlled rectifier (SCR) amplifiers were not included; no commercial packages are being offered at present, although there is little question about the ultimate potential of the SCR amplifier.

It is interesting to note that although there are a large number of special vacuum tube servo amplifiers being offered, the hi-fi amplifier predominates the field. A surprising number of these hi-fi amplifiers are ideal for driving two phase servo motors; their only drawback is a low output impedance. This handicap can be overcome by either changing the output transformer or by using the primary of the present output transformer, at its screen tapes, as an autotransformer. The result with the autotransformer output produces a less than optimum match, but with the great excess of economical power available in the hi-fi amplifiers, it is still a practical alternative.

The thyratron amplifiers are really very interesting from an engineering standpoint. Their main advantage is that a thyratron is more of a switch than is a saturable reactor. A thyratron will turn-on with no reference whatever to the magnitude of the load. To turn-on, the thyratron is sensitive to only the anode and grid voltages. The firing point, however, does vary with tubes and environmental conditions requiring a sharp firing command to the thyratron and one of the best thyratron driver sources is a small magamp.

This last point brings up the tremendous number of alternatives and circuits, in every type of amplifier, not mentioned in our Audio Frequency Amplifier series for want of complete knowledge and space. For the thyratron amplifiers, however, a very comprehensive discussion by J. H. Burnett can be found in J. G. Truxal's "Control Engineer's Handbook."

If we were to predict the future of Audio Frequency Power Amplifiers, there would be little doubt about the growth of the silicon controlled rectifier amplifiers. The SCR acts almost exactly as does a thyratron, with current as the controlling quantity instead of voltage. In this way, the SCR seems very likely to take over not only the role of the thyratron, but also the applications of the magamp. The greatest drawback to the SCR at present is their high cost. If they follow the same path as the transistor, which they seem to be doing, their cost will continue to drop: and as their cost drops, their use will increase.

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3. Extra Heavy Duty—Compression Ult. Load 3050 lbs.; Ult. tension 3900 lbs.
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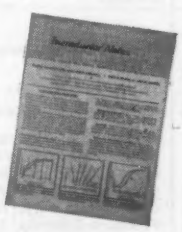

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SUMMARY OF PERFORMANCE CHARACTERISTICS OF AUDIO POWER AMPLIFIERS

MAGNETIC AMPLIFIERS

1. Company name	Acromag	Airborne	Airpax	Comp. Corp.	Control Data		Feedback Controls	
2. Model No.	224	R-8784	M-5178	-----	A 7220*	A 7200	D-4	D-10
3. Max. power into rated load (watts)	3.5	27	6	10	2.5	9	4	10
4. Recommended motor load	400 cps Size 11 servo	400 cps 25 ohms	400 cps BUord MK 7	400 cps servo	400 cps Cedar, 2200	400 cps BUord Mark 8 Mod 0	400 cps BUord Mk 14	400 cps BUord Mk 8, Kearfott R 111
5. Time delay or time const. (msec)	-----	50	Approx. 40	-----	2.5	2.5	2.5	2.5
6. Gain	medium	6.5 v/v	8 x 106 w/w with preamp	-----	500 w/w	300 w/w	3.8 v/v	29 v/v
7. Max. output v (volts rms)	-----	26	-----	Approx. 20	26	50	57 or 115	120
8. Input impedance (ohms)	-----	2000	250	-----	10,000	6000	100*	100*
9. Power required	115 vac	115 vac	115 vac	26 vac	115 or 26 vac	115 vac	115 vac	115 vac
10. Amb. temp. range (C)	-55 to 85	to 125	-55 to 105	-----	-55 to 100	-55 to 85	-55 to 100**	-60 to 100**
11. Type of circuit	reactor	dc input	dc input, full wave reactor	reactor	-----	-----	ac or dc input half wave	ac or dc input half wave
12. Environment	Mil-E-5272A Mil-T-27-A	for mil use	-----	Mil-T-27A	Mil-E-5272B	Mil-E-5272B	-----	-----
13. Size; weight (cu. in., oz.)	5.8, 8.5	21.6, 18.4	8.7, 11	3.8, -----	8.1, 12	27.6, 24	8.2, -----	14.9, less than 20
Remarks		Avail. in modular boxes with preamps	Oper. both windings of 2 phase motor		Gain adj. with ext. resistor. *with silicon transis. preamp		*as seen by external transistor preamplifier **must be mounted on adequate heat sink	

1. Company name	Feedback	Freed Transformer Co.		Kearfott Div., General Precision, Inc.		LFE
2. Model no.	D-20	MAF-4*	MAF 1*	RH 602-1	RH 604	AM-10*
3. Max. power into rated load	20	10	15	10	2.7	36
4. Recommended motor load	400 cps BUord Mk 15, Kearfott R 112	400 cps, Kearfott R110-2, R111-2	60 cps Diehl Fpe25-11	400 cps Kearfott R111-2	400 cps Kearfott R118	150 ohms 0.3 henry
5. Time delay or time const. (msec)	2.5	5 max.	32 Max.	-----	-----	5
6. Gain	29 v/v	High	High	High w/w	High w/w	40,000 w/w
7. Max. output v (volts rms)	120	57.5	110	115	26	-----
8. Input impedance (ohms)	100*	-----	-----	-----	-----	6,000
9. Power required	115 vac	115 vac	115 vac	115 vac	115 vac	120 v at 1700 cps
10. Amb. temp. range (C)	-60 to 100**	-55 to 75	-55 to 75	-55 to 125	-55 to 125	-55 to 125
11. Type of circuit	ac or dc input half wave	ac input half wave	ac or dc input half wave	dc input, full wave transformer	dc input, full wave transformer	-----
12. Environment	-----	-----	-----	Mil-T-27	Mil-T-27	Mil-E-5272A Mil-I-6181B
13. Size; weight (cu. in., oz.)	14.9, 24	8.9, 13	270.4, 336	14.6, 25.7	6.9, 11.5	125, 96
Remarks	*as seen by ext. trans. preamp. **mount on adequate heat sink.	*when used with transistor preamplifier		Parallel capacitance required in control circuit. Output v is in quadrature with excitation, motor load must be tuned.		*controller incorporating magamp

1. Company name	Lumen, Inc.		Magnetic Amplifiers, Inc.				Vickers	Westbury
2. Model No.	1057	1087	TMA-41001-KX	TMA-40601-KX	TMA-40501-KX	TMA-41601-KX	2805	SR-4, RM-1
3. Max. power into rated load	3.1	-----	10	6	3.5	16	6.5	2.5
4. Recommended motor load	400 cps, Kearfott RB118	400 cps, Oster 18-5201-04	400 cps BUord Mk 8, Kearfott R111	400 cps BUord Mk 7, Kearfott R110	400 cps BUord Mk 14, Kearfott R119	400 cps Kearfott R112	60 cps, 300 ohms	400 cps Kearfott R118
5. Time delay or time const. (msec)	2.5	2.5	1.3	1.3	1.3	1.3	16	-----
6. Gain	750 v/v	350 v/v	1.5×10^5 w/w	9×10^4 w/w	5×10^4 w/w	2.5×10^5 w/w	200 w/w	High w/w
7. Max. output v (volts rms)	26	38	57.5	57.5	57.5	57.5	50	26
8. Input impedance (ohms)	500*	6000	5000	5000	5000	5000	500	-----
9. Power required	102 vac	115 vac	115 vac	115 vac	115 vac	115 vac	120 vac	115 vac
10. Amb. temp. range (C)	-65 to 165	-55 to 85	-55 to 100	-55 to 100	-55 to 100	-55 to 100	-----	-----
11. Type of circuit	dc input	ac input	ac input	ac input	ac input	ac input	ac or dc input	dc input, full wave, transf.
12. Environment	Mil-E-5272A	meets mil specs	Mil-E-5400, Mil-E-5272A	Mil-E-5400 Mil-E-5272A	Mil-E-5400, Mil-E-5272A	Mil-E-5400, Mil-E-5272A	-----	Mil-T-27A
13. Size; weight (cu. in., oz.)	36.7, -----	27.6, -----	32.7, 20	11.2, 14	6.5, 10	48.2, 30	2.9, 4	4.2, -----
Remarks	*supplied with 2 isol. contr. windings, each 500 ohms	Dyn. braking, 250 to 350 ma dc (av.) 0 input signal	Transistor preamp internal		Transistor preamp internal			

BUYER'S GUIDE

The above tables are not intended to be complete, but rather to be illustrative of available types to facilitate preparation of realistic specifications. No assumptions should be made about omitted data; consult the manufacturer prior to final selection.

Acromag, Inc., 22515 Telegraph Rd., Southfield (Detroit), Mich.
Airborne Accessories Corp., 1414 Chestnut Ave., Hillside, N. J.
Airpax Electronics, Seminole Div., Fort Lauderdale, Fla.
Components Corp., 2855-57 N. Halstead St., Chicago, Ill.
Control Data Corp., Cedar Engrg., 5806 W 36th St., Minneapolis, Minn.
Feedback Controls, 8 Erie Drive, Natick, Mass.
Freed Transformer Co., 1718 Weirfield St., Brooklyn, N. Y.
Kearfott Div., General Precision, Inc., 1150 McBride Ave., Little Falls, N. J.
Laboratory for Electronics, Inc., 1079 Commonwealth Ave., Boston, Mass.
Lumen, Inc., Moen Ave., Joliet, Ill.
Magnetic Amplifiers, Inc., 632 Tinton Ave., New York, N. Y.
Vickers, Inc., Electric Prods. Div., 1815 Locust St., St. Louis, Mo.
Westbury Electronics, Westbury, L. I., N. Y.

SUMMARY OF PERFORMANCE CHARACTERISTICS OF AUDIO POWER AMPLIFIERS

TRANSISTOR AMPLIFIERS

1. Company name	Airborne	M. Ten Bosch				Bulova Watch	
2. Model no.	R-8780	1800-3300	1800-0300	1800-0300-2	1800-3100	AMP-576-1	AMP 424-12
3. Max. power into rated load (watts)	25	3.5	6.1	8	8	3.5	12
4. Recommended motor load	400 cps, 50 ohm, center tapped motor	400 cps Kearfott R119-5	400 cps Kearfott R110-5	400 cps	60 cps Kearfott R160-5	400 cps 450 ohm	400 cps 100 ohms
5. Bandwidth (cps)	High	High	High	High	High	100	100
6 Gain	11 w/v	2500 v/v at 10 v output	3000 w/v at 3.5 w output	30,000 v/v at 2 w output	900 w/v at 0.5 w output	2500 v/v	1000 v/v
7. Max. output v (volts rms)	35	20	40	40	25	40	40
8. Input impedance (ohms)	500	5000	10,000	200	10,000	10,000	50,000
9. Power req.	28 vdc, 1 5amps	28 vdc at 100 ma	28 vdc at 350 ma	28 vdc at 500 ma	28 vdc at 1 amp (max.)	7 watts	18 watts
10. Amb. temp. range (C)	to 71	-55 to 100	-55 to 71	-55 to 71	-12 to 52	-55 to 125	-55 to 125
11. Environment	Mil use	Mil-E-5400A	Mil-E-5400	Mil-E-5400A	-----	Mil-E-5400 Mil-E-5272	Mil-E-5400A Mil-E-5272A
12. Size, weight (cu. in., oz.)	19.2, 18.4	5.2, 4.5	7.9, 7	13, 9	45, 16	1.5, 1	7.2, 8
Remarks	Modular boxes with preamps	Adj. internally to provide essentially 90° phase shift		Carrier phase shift adj. to 0°	Power s'ply 110 v, 60 cycle avail.	Phase shift is 10° max. under linear operations at 400 cps 30° (20°) max. over entire b'ndwidth	

1. Company name	Control Tech.	Daystrom, Inc.	Diehl Mfg. Co.	Hoover Elec.	Industrial Control	Kearfott
2. Model no.	200	Size 11	FPE 21 L	D-3320	762A*	A 3105-02
3. Max. power into rated load (watts)	3.5	3.5	1	80	9	2.5
4. Recommended motor load	400 cps	400 cps, center tapped motor	60 cps, Diehl FPE21 L-28-9	400 cps, Diehl FPF-49-19-1	60 cps, center tapped servo	400 cps, R119-5 R124-5, R807-5, R809-25
5. Bandwidth (cps)	High	High	High	High	High	High
6. Gain	2500 v/v	2500 v/v	4.5×10^6 w/w	-----	High	100-1000 v/v
7. Max. output v (volts rms)	-----	36	36	-----	40	33
8. Input impedance (ohms)	-----	10,000	4000	-----	100,000	1000
9. Power req.	28 vdc	28 vdc	28 vdc at 0.3 amp	-----	20 watts of line pwr	28 vdc, 200 ma (max.)
10. Amb. temp. range (C)	-55 to 125	-55 to 100	-----	-65 to 160	Max. 71	-55 to 110
11. Environment	Mil-E-5272A	-----	-----	10g vibration, 15g shock	-----	Mil-E-5272A
12. Size, weight (cu. in., oz.)	1.12, -----	Approx. 1, 2.1	9, 6	-----, 38	74.8, 52	1.9, 2.2
Remarks	Gain adj. by ext. resis. Gain stab. is 2 db.	Gain adj. by ext. resistor		Operates dc or 3 phase motors	*includes damping ntwks, voltage and pwr amps and pwr s'ply. Adj. error rate damping, 90° carrier phase shift.	Gain adj. by ext. resistor

1. Company name	Kearfott			Magnetico	Westamp
2. Model no.	T 3103	A 3106	A3300-01	T 2000	A 419
3. Max. power into rated load (watts)	5	6	16	3.5	6.5
4. Recommended motor load	400 cps, Kearfott R110-5, R119-5, R124-5	400 cps, Kearfott R124-5, R119-5 R110-5	60 cps, Kearfott V160-001, R160-5	400 cps, center tapped motor	400 cps, center tapped motor
5. Bandwidth (cps)	High	High	High	High	High
6. Gain	1000 w/v	10-1000 v/v	1600 v/v	1000 w/v	2500 v/v
7. Max. output v (volts rms)	40	40	40	40	40
8. Input impedance (ohms)	4000-40,000	4000-40,000	5000-100,000	10,000	10,000
9. Power req.	28 vdc	28 vdc, 10.5 w	25 w line pwr	28 vdc	115 v at 0.13 amps
10. Amb. temp. range (C)	-55 to 71	-55 to 125	0 to 50	-55 to 100	-55 to 150
11. Environment	Mil-E-5272A	Mil-E-5272A	-----	existing mil specs	-----
12. Size, weight (cu. in., oz.)	6, 4.7	5.8, 6	162, 92	1, 1	6.6, 8
Remarks	Gain adj. by ext. resistor	Gain adj. by ext. resistor	Convertible to 400 cps operation. Gain adj. by ext. resistor.	Feedback connection to adjust gain.	Typ. gain stability 20% over temp. range.

BUYER'S GUIDE

The above tables are not intended to be complete, but rather to be illustrative of available types and to facilitate preparation of realistic specifications. No assumptions should be made about omitted data; consult the manufacturer prior to final selection.

Airborne Accessories Corp., 1414 Chestnut Ave., Hillside, N. J.

M. Ten Bosch, 80 Wheeler Ave., Pleasantville, N. Y.

Bulova Watch Co., Electronics Div., 40-06 62nd St., Woodside, N. Y.

Control Technology Co., 1186 Broadway, New York, N. Y.

Daystrom, Inc., Transicoil Div., Worcester, Penna.

Diehl Mfg. Co., 1129 Finderne Ave., Somerville, New Jersey

Hoover Electric Co., 2100 So. Stoner Ave., Los Angeles, Calif.

Industrial Control Co., 805 Albin Ave., Lindenhurst, L. I., N. Y.

Kearfott Div., General Precision Inc., 1500 McBride Ave., Little Falls, N. J.

Magnetico, Inc., 6 Richter Court, East Northport, L. I., N. Y.

Westamp, Inc., 11277 Mass. Ave., Los Angeles, Calif.

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Write No. 342 in Box on Inquiry Card

Linear Actuator

Eight oz. linear actuator with a 28-volt dc motor is rated at six inches per minute at 50 lb. operating load and will move loads in excess of 200 lbs. Actuator package includes four adjustable limit switches, non-jamming mechanical stops, one inch electrical stroke, adjustable end fitting and electrical connector in an environment proof envelope one inch by two inches by 4.2 inches between mounting centers. Unit complies with MIL-A-8064, MIL-M-8609 and MIL-E-5172. Nash Controls Inc., Newark, N.J.

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Packaged Assembly Service

Daven has established a completely new Packaged Assembly Department. This group assembles various components on Daven rotary switches, does all internal wiring, any external cabling necessary, and pre-tests the entire package. In switch wiring, tiis very often easier and less time consuming to wire and make connections to switch decks before they are stacked as a completely tested sub-assembly, instead of amixed group of components and switches which ordinarily would have to be individually checked, assembled, soldered and tested. Daven takes complete responsibility for the design, fabrication, testing and overall reliability of this assembly package. The Daven Co., Livingston, N.J.

Write No. 602 in Box on Inquiry Card

Indicators

Transistor Elec. Corp. is believed to be the first to offer wire wrap terminals on neon and incandescent, standard or transistor driven indicators. Units contain either permanent or replaceable lamps. Transistor Elec. Corp., Minneapolis, Minn.

Write No. 368 in Box on Inquiry Card

Subminiature Relay

Designed with 0.2 inch grid space, six-pole, double-throw relays occupy less than a cu. in. of space and weigh 1.8 ozs. The hermetically sealed dc unit withstands shocks of 50g and vibrations of 28-2000 cps at a constant 20g and 5-28 cps at 0.5 in. double amplitude. Standard coils include nominal voltage ratings from 6 to 115 volts dc with a power rating of approximately 2.5 watts. Allied Control Co., Inc., New York, N.Y.

Write No. 314 in Box on Inquiry Card

Vibration Test Measurement

A simplified method for measuring displacement in vibration testing is available without charge from MB Electronics, a division of Textron Electronics, Inc. The "optical wedge" is a pressure-sensitive wedge-shaped sticker that can be affixed to a flat surface on an object under test. The long axis of the wedge should be exactly perpendicular to the axis of vibration. Then, as the wedge vibrates with the piece under test, two triangles will appear. Displacement is indicated on scale directly below point of the darkest triangle. MB Electronics, New Haven, Conn.

Write No. 337 in Box on Inquiry Card

Glass-Enclosed Resistor

With the glass enclosure hermetically sealed, a resistor has zero moisture absorption. A tin-oxide film, fired into the surface of a glass rod, gives the unit outstanding ability to endure heat, humidity and repeated overloads. ⅛-watt and ¼-watt models have a resistance range of 100 to 360 ohms. Voltage ratings are 250 and 300v with rating to 150 C. Corning Glass Works, Corning, N.Y.

Write No. 513 in Box on Inquiry Card

Four-Way Toggle Switch

Eight-pole, double-throw contacts assembly is made up of four pairs of snap-action switches with electrical ratings at five amps resistive, three amps inducstive, at 30 volts dc and 115 volts ac. From the center position it is possible to actuate double-pole double-throw circuitry in each of the four momentary positions spaced 90° apart. Dimensions are 2 3/32″ x 1 29/64″ and weight is 0.11 lbs max. Operating force is 0.5 lbs. Haydon Switch, Inc., Waterbury, Conn.

Write No. 518 in Box on Inquiry Card

Core Magnet Meter

Self-shielded movement of a core magnet meter needs no special calibration and can be mounted directly into virtually any type of panel without compensation. The meter is said to have a high torque to weight ratio, extreme linearity, high density sintered poles and shock mounted jewels. The core magnet movement can be used to construct light meters, vacuum tube voltmeters, signal generators, geiger counters, battery testers, etc. It also can be used as a finished meter in any of its applications. Ideal Precision Meter Co., Inc., Brooklyn, N.Y.

Write No. 670 in Box on Inquiry Card

Subminiature Actuators

With high specific energy output, subminiature ballistic actuators can replace solenoids in many aircraft and missile applications. Models are offered for either push or pull action, in a range of predetermined strokes, and force outputs to 25 lbs. Various electrical firing characteristics are provided. Unit measures 0.5 X 0.6 X 0.38″ and weighs four grams without leads. Propellex Chemical Div., Chromalloy Corp., Edwardsville, Ill.

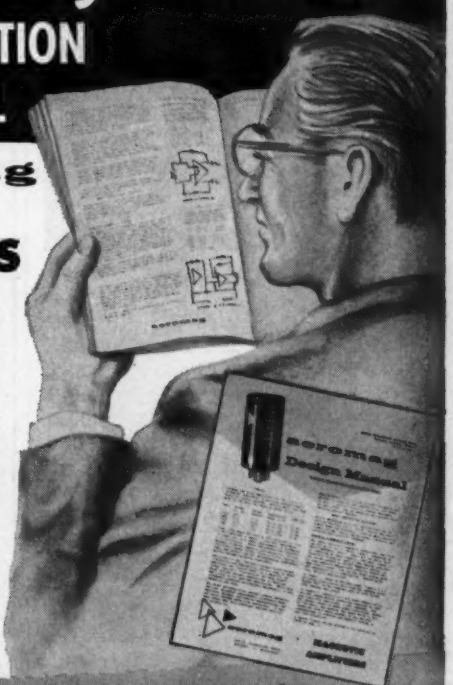
Write No. 326 in Box on Inquiry Card

3000F Thermocouples

Two types of thermocouples are usable above 3000F. A rhodium-iridium/iridium thermocouple is useful for applications in vacuum or inert atmospheres, up to 3600F. Tungsten-rhenium thermocouples are said to be outstandpheres, and particularly oxidizing atmospheres, up to 3600F. Tungsten-rhenium thermocouples are said to be outstanding in stability and power for applications in other than oxidizing atmospheres up to 4000F and potentially to temperatures approaching 5000F. Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.

Write No. 319 in Box on Inquiry Card

HOW to SOLVE *Tough Problems* in INSTRUMENTATION and CONTROL



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MAGNETIC AMPLIFIERS

Magnetic Amplifier Design Manual, Bulletin 403-A, shows you how to solve tough design problems. It has 45 schematic diagrams and graphs showing magnetic amplifier applications and design techniques. Also, it shows precision voltage comparators magnetic integrators, null detectors, accurate temperature controls, magnetic summing networks, Laplace transforms, etc.

Copies normally cost $1.00 each, but are now available without charge to qualified design engineers who request a copy on their company letterhead. Write to . . . . . .

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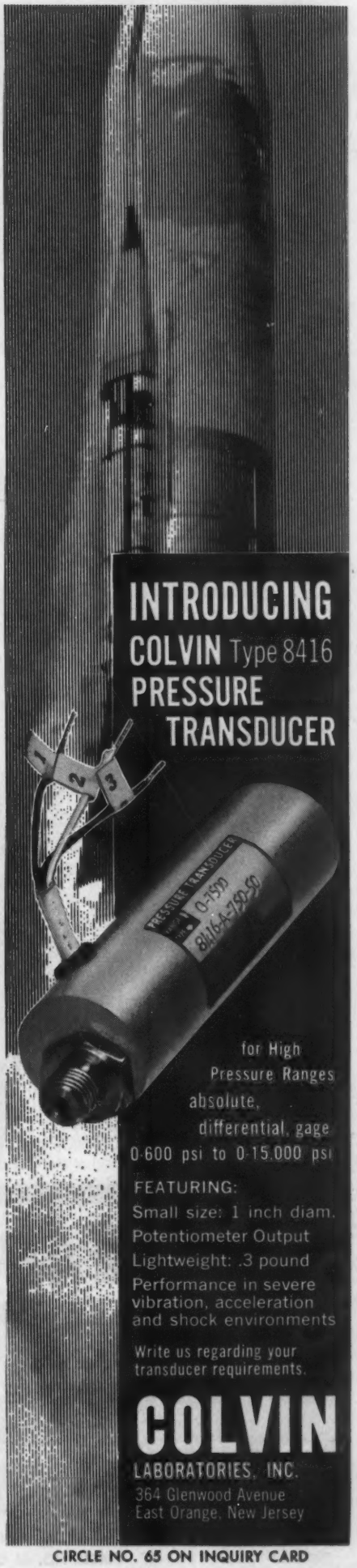

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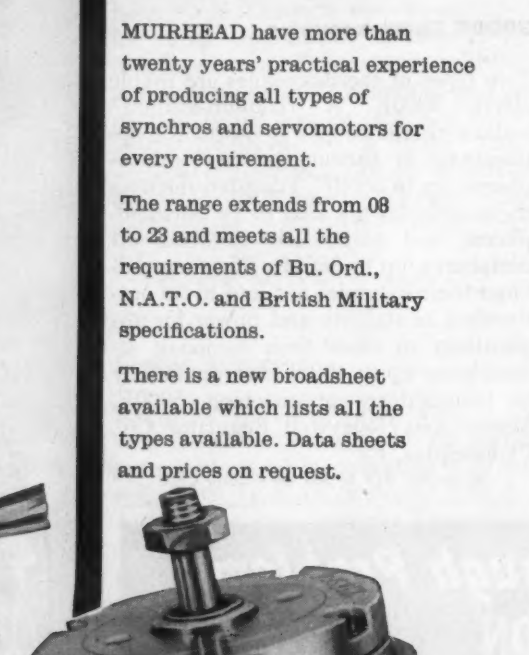
SYNCHROS?

Go Straight to MUIRHEAD!

MUIRHEAD have more than twenty years' practical experience of producing all types of synchros and servomotors for every requirement.

The range extends from 08 to 23 and meets all the requirements of Bu. Ord., N.A.T.O. and British Military specifications.

There is a new broadsheet available which lists all the types available. Data sheets and prices on request.



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Telephone: Beckenham 4888

454

CIRCLE NO. 66 ON INQUIRY CARD

ELECTROMECHANICAL COMPONENTS

Slide Switches

For easy assembly in end products, four-pole slide switches are designed with all terminals in a common plane. All teminals and contacts are silver plated and standard units feature the "short" terminal, with an overall distance, from mounting surface to extreme tip of terminal, of 0.575 in. Continental-Wirt Electronics Corp., Philadelphia, Pa.

Write No. 430 in Box on Inquiry Card

Piezoelectric Transducers

For ultrasonic non-destructive testing, transducers employing a ferroelectric element are available in standard sizes from 200 kc to 10 mc. Units are compatible with all types of equipment without modification and are available with any standard connector. Automation Industries, Inc., Boulder, Colo.

Write No. 494 in Box on Inquiry Card

Miniature Printer

Printing speeds of more than 30 characters per second on 5/16″ tape are attained by a printer 9¼″ long. With a self contained paper supply, the printer fits a standard 3″ instrument case. The unit is particularly useful for computer output and for weapons system checkout devices. Cost is less than $500.00. Potter Instrument Co., Plainview, N.Y.

Write No. 439 in Box on Inquiry Card

Thermostats

Bimetal disc thermostats can be supplied on special order with differentials of 1 to 4 F, Standard units are available with differentials of 2 to 6 F. Stevens Mfg. Co., Mansfield, Ohio.

Write No. 444 in Box on Inquiry Card

Proximity Switch

Operation of a magnetically actuated proximity switch is accomplished without any physical contact by the movement of a tiny magnet within proximity of the switch. The device can control a wide range of circuits, including high speed counters, automation actuators and tamper alarms. Hermetic sealed and encapsulated in a high temperature synthetic resin, the switch meets water, oil and explosion proof specifications. Life expectancy is in excess of one billion operations. Electro-Seal Corp., Des Plaines, Ill.

Write No. 671 in Box on Inquiry Card

Gyros

Design enables a conventional free gyro to be readily modified to a directional or vertical gyro. Unit small size results from a high momentum-to-weight ratio motor, compact assembly of major components and elimination of the conventional electromechanical caging system. The gyros operate in rigorous environments. Kearfott Div., General Precision Inc., Little Falls, N.J.

Write No. 509 in Box on Inquiry Card

Solid State Transducer

Displacement transducers with built-in solid stat circuitry operate with dc excitation and provide a dc output signal. Solid state circuitry is said to permit direct operation of recorders, indicators, etc. G. L. Collins Corp., Long Beach, Calif.

Write No. 507 in Box on Inquiry Card

Photoelectric Reader

Miniature photoelectric device combines a light source, a single lens and a photocell within one highly compact unit, making it adaptable to various mountings in small, limited-access areas. Lens arrangement eliminates the need for lens alignment. Melpar, Inc., Falls Church, Va.

Write No. 438 in Box on Inquiry Card

Hi-Temp Motor

Designed for an ambient temperature range of −65 to +600 F, a motor uses nickel-clad copper wire insulated by glass that is impregnated with a specially developed high-temperature additive. Bearing material, stator plating, etc. were chosen to assure reliability at high temperatures. Airborne Accessories Corp., Hillside, N.J.

Write No. 327 in Box on Inquiry Card

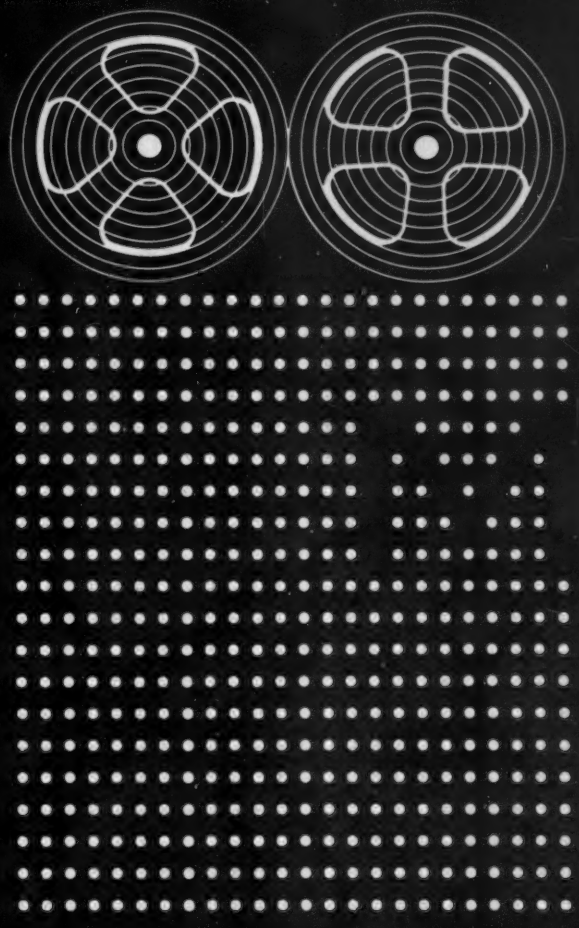
Meter-Relay

Signals as low as 2 microwatts will activate a meter relay capable of controlling up to 600 watts of output power. Driven from the output of differential transformers, strain gages, gas analyzers, bridges, temperature-sensitive elements, photocells or other similar devices the unit can sort, grade or classify, alarm, indicate or control. Operation is continuous without the need for re-set circuitry. Electric Regulator Corp., Conn.

Write No. 457 in Box on Inquiry Card

imc

HYSTERESIS and TORQUE MOTORS



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For tape and data processing systems — and related applications which require unusually high performance and reliability. Single, dual, 3 & 4 speed, ball or sleeve bearings, 1/2500 H.P. to ¾ H.P., 60 cps, 400 cps and other frequencies . . . many alternate specifications to meet your exact needs . . . also miniature hysteresis-synchronous and geared-synchronous motors in size 8 through size 18 ■ This IMC line of hysteresis and torque motors features new advances in miniaturization and production economy . . . is also characterized by uniform speed, low noise level, and high-starting torque ■ IMC engineers will work closely with you . . . help you design your equipment or system smaller, better with the motor that completely meets your particular requirements ■ Write for additional technical information to:

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CIRCLE NO. 77 ON INQUIRY CARD

General Electric RTV* LIQUID SILICONE RUBBER

Cures at room temperature, useful from −70°F to +600°F

General Electric's expanding family of RTV silicone rubber compounds all cure at room temperature. They contain no solvents; resist temperature extremes, moisture, ozone, weathering and aircraft fuels. Available in a wide range of viscosities from 120 poises (lower than any other silicone rubber compound) to 12,000 poises. Important application areas include:

SEALING AND CAULKING

Aircraft manufacturers use RTV for pressure sealing of cabins and cockpits, fire walls, fuel tanks and hot air ducts. Protection for electronic packages is provided by caulking assemblies and sealing seams and lead holes with RTV.

ELECTRICAL INSULATION

Good electrical properties and outstanding heat resistance have led to RTV's use in coil impregnation and encapsulation of motors and transformers. Can be poured, sprayed, painted, or applied by dipping. Cure times can be varied from minutes to several days.

MOLDING AND TOOLING

Parts cast in flexible RTV molds reproduce with precision detail. Built-in parting agent assures easy release. RTV eliminates such common problems as excessive shrinkage and separate release agents.

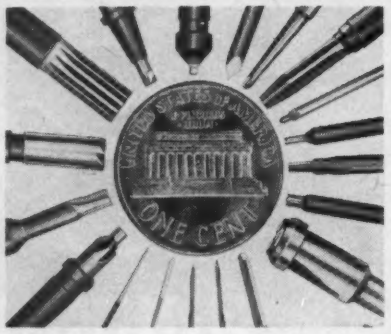
*Room Temperature Vulcanizing

For more information and a free test sample, write (briefly describing your application) to General Electric Company, Silicone Products Department, Section 40, Waterford, N.Y.

GENERAL ELECTRIC

CIRCLE NO. 70 ON INQUIRY CARD

New Mechanical Components For Electromechanical Systems



Micro-Miniature Machine Cutting Tools

As typified by the line of taps which go down in size to .012" diameter with 338 threads per inch, a complete line of micro minature tools will be of great benefit where miniaturization of equipment and components is most important. Among the other tools in the line are spotters, drills, reamers, broaches, countersinks, counterbores, dies, hollow end mills, face mills, lip mills, routing cutters, keyway cutters, fly cutters, poising and circular saws. Waltham Precision Instrument Co., Waltham, Mass.

Write No. 552 in Box on Inquiry Card

Sensory Bellows

Lightweight, sensory bellows, fully machined, were designed for a maximum pressure differential of 100 psi and a temperature range of −450 to +1000 F. Hysteresis is said to be almost zero due to the machined bellows design. Under test conditions unit withstood over 10,000,000 cycles without metal fatigue. Hydrodyne Corp., North Hollywood, Calif.

Write No. 322 in Box on Inquiry Card

Self-Sealing Couplings

For use in aircraft fuel, oil, low pressure hydraulic, pneumatic, and other systems, self-sealing couplings provide fast, safe connections in applications where positive, foolproof locking is mandatory. Three check points are used to verify positive connection: sound; an audible click action, visual; indicator pins protrude externally when coupling is locked, touch; position of indicator pin can be determined manually. Couplings have been fully tested in accordance with Mil-C-7413A. Aeroquip Corp., Jackson, Mich.

Write No. 309 in Box on Inquiry Card

Sizes 11 Synchros

Complete line of size 11 synchros meeting MIL-S-20708 are stable over the temperature range of −55 to +85C. Thru-bore construction and mechanical and electrical symmetry assure high accuracy and long life. Units are available with accuracy of 3 minutes of arc. Ketay Dept., Norden Div., United Aircraft Corp.

Write No. 78 in Box on Inquiry Card

Self-Aligning Slides

Slides incorporate new principle that eliminates the need for shimming. Built-in flat groove design produces the same efficient slide action found in perfectly aligned slides. Units automatically adjust to fit misaligned chassis' and cabinets eliminating the need to shim. Slides meet military specs. for material and finish. Grant Pulley & Hardware Corp., West Nyack, N.Y.

Write No. 421 in Box on Inquiry Card

Force Gages

Precision mechanical force gages are designed for measuring tension in a permanent test set-up. The force indicator's free-floating transmission rod transmits the tension load to a dial indicator. One end of the rod is threaded for mounting in test apparatus or fixtures. Units are available in capacities ranging from 20 to 500 lbs. Accuracies range from ±0.1 to±2½ lbs. The gages can hold the maximum dial reading after the load has been removed, making it useful for measuring momentary or transient loads. Hunter Spring Co., Lansdale, Pa.

Write No. 426 in Box on Inquiry Card

New Electronic Components For Electromechanical Systems

Silicon Power Transistors

Diffused-junction NPN transistors are designed for power-switching and amplifier applications operating in the temperature range of 65 to 200 C. Collector to emitter voltage is 80 volts for types 2N1047 and 2N1049 and 120 volts for 2N1048 and 2N105. Power dissipation is 40 watts at case temperature of 25 C. Units are hermetically sealed in a stud mounted welded case and meet Mil-S-19500B. Silicon Transistor Corp., Coile Place, N.Y.

Write No. 441 in Box on Inquiry Card

Digital Building Blocks

Ten basic types and 15 variations of digital modules, vacuum encapsulated with epoxy resin, contain up to 35 standard components per cu. in. Modules satisfy Mil-E-5272D (ASG) requirements with all components meeting military requirements. Units have a standard height of 0.8 in. and length of 1.0 in. Width varies in multiples of 0.2 in. from 0.4 in. to 1.0 in. Pins are provided for dip soldering to printed circuit boards or for resistance welding to interconnecting wiring. Logic levels are zero and 6 volts and a power inverter, capable of driving 30 modules, can be used when load requirements are excessive. Delco Radio, Kokomo, Indiana.

Write No. 449 in Box on Inquiry Card

Contact Protection Devices

Designed to solve the problem of destructive arcing due to inductive voltage surges at contact points, protection units extend the life of contact up to 100 times. Available with pigtail leads, the units will serve all relays operating up to 40 times per second and which draw up to 200 ma operation current at 130 volts ac or 250 ma at 154 volts dc; ratings based on operation in an ambient temperature of 25C. Units encased in phenolic tubing have a maximum width of ⅜ inches, with length ranging from 5/8" to 15/16" max. Plastic encapsulated assemblies have a maximum length of 0.380 in., widths ranging from 0.340 in., to 0.380 in. General Instrument Corp., New York, N.Y.

Write No. 303 in Box on Inquiry Card

Magnetic Head Readout

Multiaperture device employs only ferrite cores and wire to provide intrinsic and non-destructive readout of stored data in digital and analog applications. The device transfers information simultaneously from a central data source to a number of inputs with a readout rate adjusted to the clockrate of each input. In applications requiring visual display, the unit used as a shift register offers sufficient voltage to drive incandescent lamps or indicating devices without diodes, capacitors or transformers. In analog computers, the device's high degree of linearity between remnant magnetic flux and applied drive makes possible the storage of data for an indefinite period. A.M.P. Inc., Harrisburg, Pennsylvania.

Write No. 306 in Box on Inquiry Card

Tunnel Diode Curve Tracer

Curve tracer permits the study of forward characteristics of tunnel diodes including gallium arsenide types. Any sensitive oscilloscope may be used with the instrument to create current and voltage wave forms. The tracer creates a sharp representation of the entire critical region of the forward characteristics curve of the tunnel diode under test rather than just a portion of the curve. Through the use of an external decade box shunted across the horizontal terminals, the actual negative resistance of the tunnel diode at any point on the curve can be read. Texas Instruments Inc., Houston, Texas

Write No. 520 in Box on Inquiry Card

Power Resistor Decade Box

Decade box permits fast, accurate resistance and load determination and may be used as a universal power resistor, calibrator for meters or as a meter multiplier. Resistance can be changed in a working circuit without resistance breakdown between settings, thus protecting delicate meters and other instruments and components in the circuit. Unit allows selection of any resistance from 1 to 999,999 ohms in one ohm steps at a maximum power rating of 225 watts, using a maximum of 1000 volts dc or 660 volts ac. Clarostat Mfg. Co., Dover, New Hampshire.

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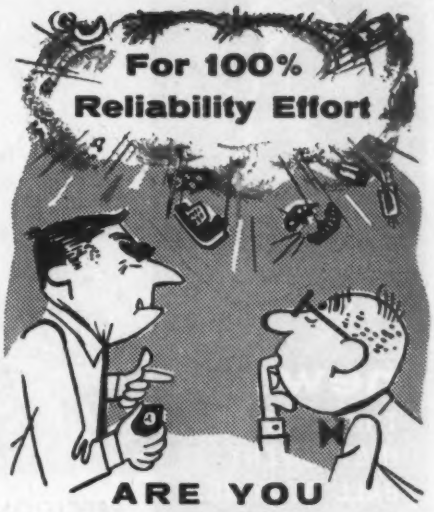

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- Consumption of rated life of critical equipment or components?
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You can reduce the odds against failure by constant monitoring and timely replacement of equipment approaching the end of assured performance . . . by thoughtful application of the . . .

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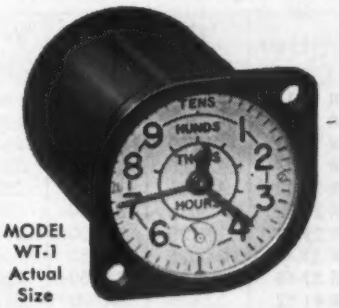

MODEL WT-1 Actual Size

1 1/16" O.D. x 1 5/16" 3 OZ.

10,000 Hour Total Readout
(Easily Read to Closest Hour)
400 CPS

Whether it's for reliability and life testing, design or system analysis, utilization studies . . . or to continuously monitor and log critical equipment or components . . . when you incorporate the Waltham WT-1 in your plans, you add that "measure of reliability" so important for military acceptance.

The WT-1 meets MIL-E-5272A and is available "FROM STOCK" Write Now for Bulletin 5001!

WALTHAM

PRECISION INSTRUMENT COMPANY
Waltham 54, Massachusetts

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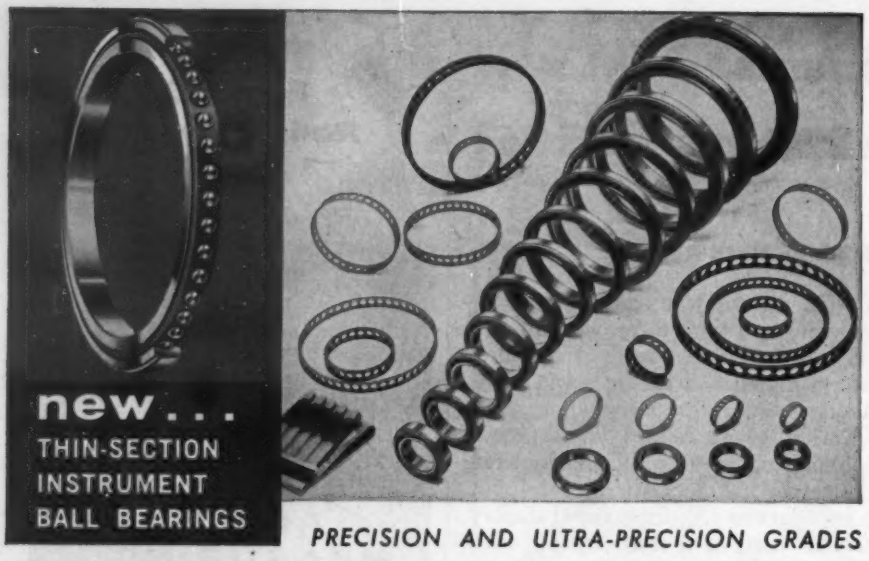
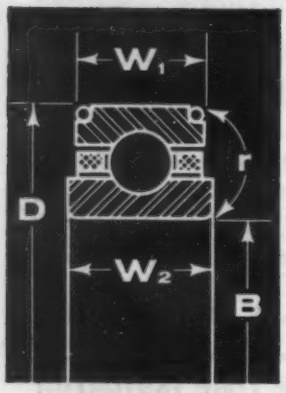


PRECISION AND ULTRA-PRECISION GRADES

TYPE TCR MAXIMUM BALL COMPLEMENT WITH ONE-PIECE RETAINER



The type TCR bearing offers the maximum radial and thrust capacity possible in a retainer-type ball bearing of these dimensions, and considerably more capacity than a conventional thin-section bearing with a two-piece retainer or spring separators. There are no filling notches and thrust capacity is two-directional.

Type TCR bearings are used for optimum performance — high speeds, high loads, and low torque. Only with the SBB design is it possible to have a maximum ball complement with a one-piece retainer, and keep the advantages of continuous race shoulders. The one-piece retainer is strong and light, precision-machined from reinforced phenolic.

Available with full ball complement (without retainer) as types TCF and TCA.

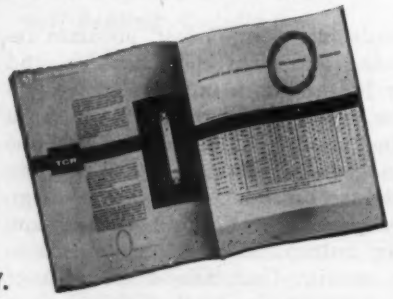
number	*B bore	*D o.d.	W_1 +.000 −.005	W_2 +.000 −.005	Balls no.	Balls size	wt. lbs.	‡L lbs.	§S lbs.
TCR 10-17	.6250	1.0625	.250	.281	18	7/64	.032	228	370
TCR 12-19	.7500	1.1875	.250	.281	18	1/8	.037	280	490
TCR 14-21	.8750	1.3125	.250	.281	20	1/8	.042	310	540
TCR 17-24	1.0625	1.5000	.250	.281	24	1/8	.05	360	650
TCR 21-28	1.3125	1.7500	.250	.281	28	1/8	.06	370	760
TCR 25-32	1.5625	2.0000	.250	.281	34	1/8	.07	390	925
TCR 29-36	1.8125	2.2500	.250	.281	38	1/8	.08	410	1030
TCR 33-42	2.0625	2.6250	.250	.281	44	1/8	.12	435	1200
TCR 37-46	2.3125	2.8750	.250	.281	48	1/8	.13	450	1300
TCR 41-52	2.5625	3.2500	.312	.375	36	3/16	.22	835	2200
TCR 45-56	2.8125	3.5000	.312	.375	39	3/16	.24	850	2370
TCR 49-62	3.0625	3.8750	.312	.375	42	3/16	.26	880	2550

Dimensions are in inches. Balls and rings of 52100 high chrome alloy bearing steel. Also available in 440 C stainless. Radius "r" will clear .015" shaft or housing fillet. *Tolerances vary according to size — see catalog 59 for Precision Grade and Ultra-Precision Grade Tolerances. ‡Radial load capacity at 500 rpm and 2500 hours average life. §Static non-brinell load capacity.

send for new catalog 59

Split's catalog 59 provides complete coverage on the complete T series of thin-section precision instrument ball bearings. No designer should be without it.

WRITE FOR YOUR COPY TODAY.



split ballbearing
A DIVISION OF MPB, INC.
525 HIGHWAY FOUR, LEBANON, NEW HAMPSHIRE

CIRCLE NO. 76 ON INQUIRY CARD

ELECTRONIC COMPONENTS

Glass Laminate

Glass silicone laminated plastic, Grade G-7, in sheets up to two inches thick, has good dielectric loss factor and insulation resistance properties under humid conditions, plus excellent heat and arc resistance. Synthane, Corp., Oaks, Pa.

Write No. 310 in Box on Inquiry Card

Miniature Chopper

Hermetically-sealed, miniature chopper package can be either directly soldered into a printed circuit board or plugged into standard transistor sockets. Operating frequencies from one to 500 cps are available with both MBB and BBM switching configurations. Temperature range is −55 to 125 C and units withstand shock to 50g and vibration of 30g from ten to 2000 cps. Residual noise is less than 15 microvolts at 400 cps into one megohm and straight through copper leads reduce thermal noise to extremely low levels. James Electronics Inc., Chicago, Ill.

Write No. 514 in Box on Inquiry Card

Servo Tester

Designed especially for servo test problems signal generators produce waveshapes necessary for frequency and transient response tests. Outputs are either low frequency signals for dc servos or suppressed carrier modulations for ac servos. Controls are provided for data frequency, signal amplitude, carrier and data phase. Unit is priced for widespread use in servo development work, laboratory demonstrations and production adjustment of critical servo parameters. Industrial Control Company, Farmingdale, L.I., N.Y.

Write No. 434 in Box on Inquiry Card

Dual Channel Amplifier

A dual amplifier for compensated resolver applications has a parallel summation input circuit that accepts up to five inputs per channel. Packaged separately, the amplifier plugs into the resistor package which mounts above or below the chassis. Voltage transfer ratios are accurate to 0.1% over the temperature range of −55 C to 105 C. Ratios from 0.1 to 10.0 can be obtained. Reeves Instrument Corp., Garden City, N.Y.

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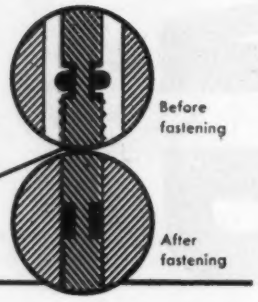
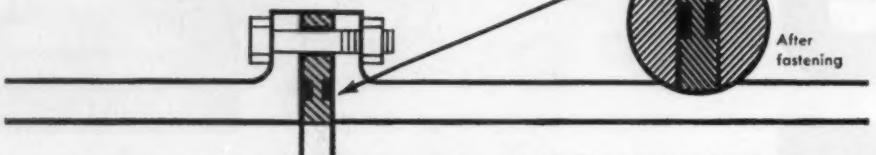
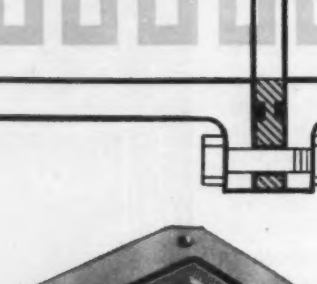
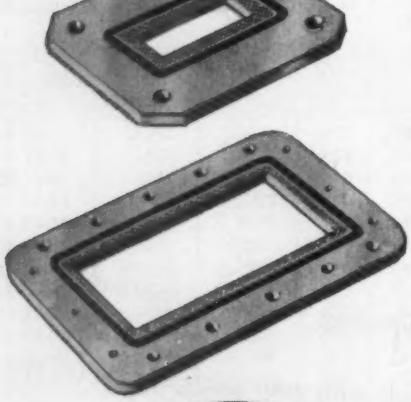
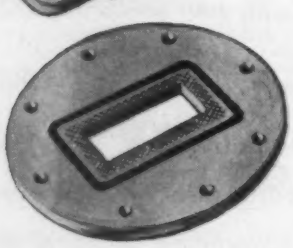
NOW THERE IS A BETTER WAY TO SEAL WAVE GUIDES











✓ **PREVENTS R/F LEAKAGE**
Metal-to-metal contact with "engraved fingers" on inside surfaces assures electrical continuity.

✓ **PROVIDES NO-LEAKAGE SEALING**
Controlled confinement of seal gland assures safe, sure, positive sealing — **exceeds** top hermetic specs!

✓ **ELMINATES ARCING AND/OR BURNING**
Designed to exacting requirements for proper mating of flanges as specified.

✓ **CAN BE RE-USED**
Seal is never "squeezed" beyond elastic limits, "memory" is constant, before, during and after fastening.

✓ **ECONOMICAL**
Eliminates cleaning or resurfacing flanges, no intricate machining required to accommodate the seal, and they're resuseable with just normal care.

✓ **STANDARDS FOR W/R SERIES**
Electr-O-Seals are available as standards to WR series Wave Guide flanges, assuring adequate supply and economy.

In addition to the standard WR series wave guide flange seals, Parker Seal Company also makes special seals to meet almost any specification or configuration. A nation wide group of field engineers are available to aid in expediting your requirements.

For more complete information **send for** catalog 5801.

Parker SEAL COMPANY
Culver City, California and Cleveland, Ohio
A DIVISION OF PARKER-HANNIFIN CORPORATION

CIRCLE NO. 71 ON INQUIRY CARD

ELECTRONIC COMPONENTS

Film Capacitors

Designed for critical applications requiring high insulation resistance and high stability, polystyrene film capacitors are available in 100, 200, 400, and 600 volt increments with ranges from 0.0047 to 1.0 mfd. Capacitance tolerance includes ±1% and 5% as standard and ±2% and 0.1% upon request. Stability is maintained to within 0.01% and less than 0.1% drift for a full year. Dielectric absorption is 0.02%. Soltys Associates, Los Angeles 29, California.

Write No. 436 in Box on Inquiry Card

Silicon Diodes

Two major classifications of diffused silicon diodes, fast recovery types and high conductance types, are designed for airborne and industrial computers. Fast recovery types provide 400,000 oms (Zrec) in 1.0μsec. High conductance types have a maximum average forward current of 100 m at 1.1 volts. Rugged construction of both units provides resistance to shock and vibration exceeding Mil-Std 202A. CBS Electronics, Lowell, Mass.

Write No. 429 in Box on Inquiry Card

Glass-Enclosed Resistor

With the glass enclosure hermetically sealed, a resistor has zero moisture absorption. A tin-oxide film, fired into the surface of a glass rod, gives the unit outstanding ability to endure heat, humidity and repeated overloads. ½-watt and ¼-watt models have a resistance range of 100 to 360 ohms. Voltage ratings are 250 and 300v with rating to 150 C. Corning Glass Works, Corning, N.Y.

Write No. 513 in Box on Inquiry Card

DC Amplifier

For converting low level dc input to ±2.5 dc output, amplifiers have continuously adjustable gain between steps of 10-100 and 100-500. Specs include: 0.5% best straight line linearity, gain stabilitly of 0.5% full scale of 25 C. value, less than 5k output impedance, and 20 mv peak-to-peak rippel (carrier). Frequency response filters are interchangeable. Unit meets Mil-E-5272 and measures 5 x 2¾ x 1¾ inches. Temco Aircraft Corp., Dallas, Texas.

Write No. 508 in Box on Inquiry Card

Silicon Diodes

Twenty silicon JEDEC diode types, 100% tinplated for resistance to salt spray, assure maximum solderability. High current loads are carried without the need for a heat sink. IN440 and IN1692 series are designed for use in applications requiring high forward conductance (to ¾ amps) and low leakage current at high temperatures (to 165 C). IN1487 and IN1492 series are designed specifically for magnetic amplifiers and power supplies. International Rectifier, El Segundo, Calif.

Write No. 411 in Box on Inquiry Card

Deviation Voltmeter

Reading directly in % deviation as well as in volts, voltmeters eliminate slide rule conversion. Unit has two scales: −100 to +100 volts and −5% to +5% deviation. Applied voltage is indicated with a ±2% accuracy. When deviation switch is pushed, the meter reads directly in % deviation of applied voltage with accuracy of +¼% to 1/10%. Two models are available; one for rack mounting, and the other a portable unit. Voltron Products Inc., Pasadena, Calif.

Write No. 437 in Box on Inquiry Card

Oscilloscope

Operating in the dc-to-450 kc range, oscilloscope contains a minimum number of tubes for a high degree of reliability. Basic sensitivity is 5 mv/cm. Vertical amplifier characteristics include: input stage electronically regulated, calibrated steps to 20 v/cm, adjustable between 12 steps and to over 50 v/cm uncalibrated and constant input impedance at all sensitivities. Tektronix, Inc., Portland, Oregon.

Write No. 459 in Box on Inquiry Card

Metalized Paper Capacitors

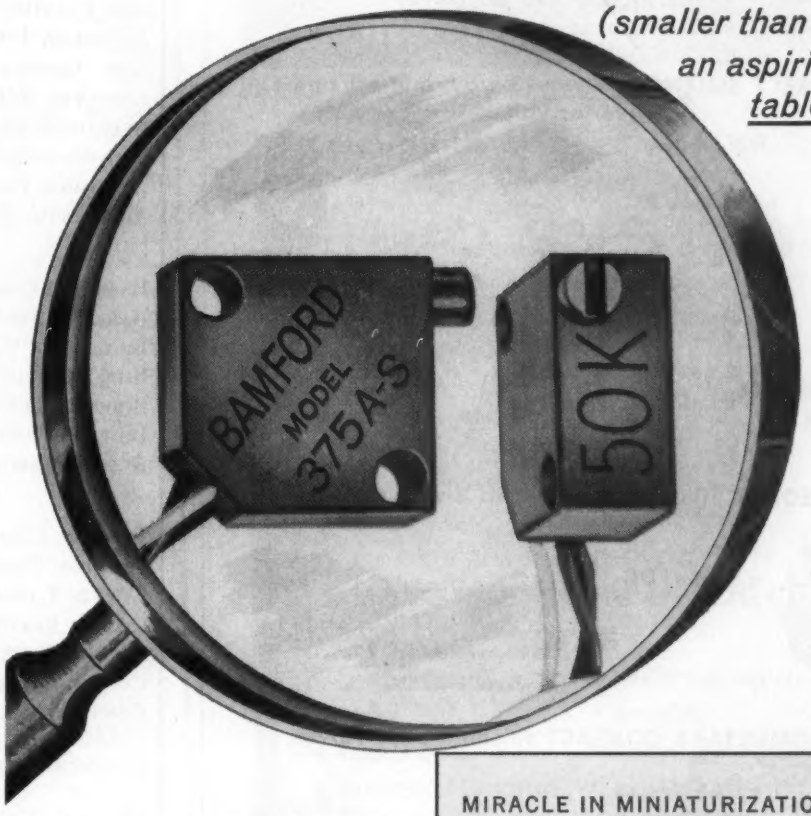
With a plastic molded case, metalized paper capacitors are protected against severe usage. The case will not dry out, develop cracks or fissures. Rectangular shape allows greater parts density. A 4.0 mfd unit measures 37/64" x ¾" x 1¾". Hopkins Engineering Co., San Fernando, Calif.

Write No. 403 in Box on Inquiry Card

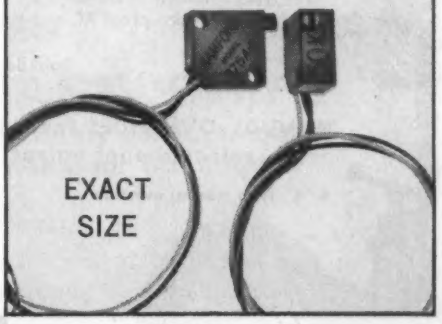
new... TRIMMING POTENTIOMETERS

Tiniest on the Market...

(smaller than an aspirin tablet)



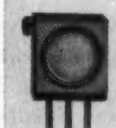
MIRACLE IN MINIATURIZATION



FEATURES

Unsurpassed accuracy and reliability, higher power rating, superior resolution, inherent stability, dual contact wiper, moisture resistance, teflon insulated lead wires, sealed for reliability under environmental extremes, precision machined aluminum case, 25-turn "0" ring sealed adjustment, meet or surpass requirements of MIL specifications.

CHARACTERISTICS



375 SERIES (all models) –
Power rating 1 watt
Resistance range 10 to 50K ohms
Dimensions 0.375x0.375x0.175"
Weight less than 1 gram

500 SERIES (all models) –
Power rating 2 watts
Resistance range 10 to 100K ohms
Dimensions 0.500x0.500x0.175"
Weight less than 2 grams

Compact, square design unexcelled for stacking arrangements.

PATENT PENDING

Engineers should investigate the outstanding advantages of these wire-wound trimming potentiometers...call or write for Brochure containing complete specifications.

A FEW SELECT TERRITORIES ARE STILL AVAILABLE TO PROGRESSIVE REPRESENTATIVES

RELIABILITY QUALITY

Potentiometer Division

BAMFORD CORPORATION

1547 18th Street
Santa Monica, California. EXbrook 3-0396

CIRCLE NO. 72 ON INQUIRY CARD

Barksdale AIR-SEAL* Valves for the nerve centers of production

** The air pressure is the sealing force; the higher the pressure, the tighter the seal.*

DIRECT SOLENOID 4-way, 3-way, shut-off and diverter valves

◆ Standard **AC**

Explosion-proof **AC** ◆

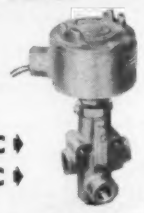
◆ Standard **DC**

Explosion-proof **DC** ◆

SOLENOID-PILOT 4-way and 3-way valves

◆ Standard **AC**

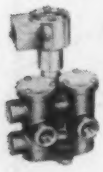
◆ Standard **DC**



Explosion-proof **AC** ◆

Explosion-proof **DC** ◆

MOMENTARY CONTACT solenoid-pilot valves



◆ Single Solenoid

Both types available in standard AC and DC and explosion-proof AC and DC.

Dual Solenoid ◆

MANUAL OVERRIDES for standard solenoid-pilot valves

◆ "L" type manual override

"MK" type manual override ◆

MANUAL and FOOT OPERATED valves

Manual 4-way

Manual shut-off

Foot operated 4-way

Write for air valve catalog (AV-9) which contains complete data and prices on 562 different valves (not counting voltage variations).

CONTROL VALVE DIVISION

barksdale valves

5125 ALCOA AVENUE • LOS ANGELES 58 • CALIFORNIA

CIRCLE NO. 73 ON INQUIRY CARD

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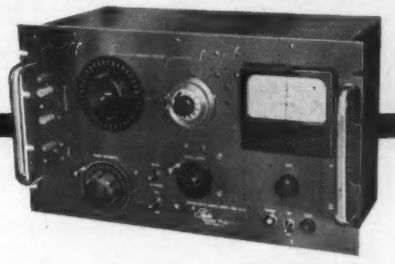
NOW!
A SINGLE INSTRUMENT TO

SIMULATE INPUTS
MEASURE OUTPUT ANGLES
RECORD DRIFT OF

SERVO SYSTEMS



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SYSTEM ERROR BRIDGE TESTS

- Inertial Platforms
- Servos
- Vertical Gyros
- Navigational Computers
- Master Transmitters
- Autopilots
- Aircraft Indicators
- Antenna Pedestals

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PHASE SHIFT
continuously through 360° at constant amplitude!

with Theta's
PHASE GENERATOR
OFF-THE-SHELF DELIVERY

Direct reading of phase shift. Accuracies from 20 min.-of-arc. Outputs to 180 volts at 5 watts. Designed as laboratory device or circuit component. Passive, rugged construction.

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MANUFACTURER OF PRECISE TEST EQUIPMENT FOR SERVO SYSTEMS.

Theta INSTRUMENT CORPORATION

520 Victor Street • Saddle Brook, New Jersey
Hubbard 7-3508 • TWX: HKK 952-U

CIRCLE NO. 74 ON INQUIRY CARD

put HEINZE in your designs

HEINZE UNIVERSAL MOTORS

Photo courtesy K. J. Miller Corp., Brookfield, Ill.

RUGGED TO POWER SMALL PAINT COMPRESSORS

. . . or marine pumps . . . or gum tape machines . . . or automobile antennas . . . or meat slicers . . . or any application demanding a quality sub-fractional horsepower motor that can take it.

In addition, Heinze Universal Motors are compact to fit limited space, have high starting and running torque, are versatile to allow all types of mounting arrangements and modifications, are uniform in quality, are keyed to high production, and are competitively priced.

Standard voltage rating is 115V AC/DC but motors are supplied for other voltages.

Send coupon for catalog.

HEINZE ELECTRIC COMPANY
685 Lawrence Street
Lowell, Massachusetts

SUB-FRACTIONAL HORSEPOWER MOTORS AND BLOWERS

Heinze Electric Company
685 Lawrence Street, Dept. ED
Lowell, Massachusetts

Please send catalog on Heinze Sub-Fractional Horsepower Motors and Blowers.

Name and Title.....

Company.....

Street and Number.....

City and State.....

CIRCLE NO. 75 ON INQUIRY CARD

For Your 3-Ring Binder

NEW DATA SHEETS

For your free copy of the data sheets listed on this page, enter the appropriate number of the item on the Inquiry Card.

High Temp. Tapes 485

Six-page brochure that can help solve many extreme high temperature design problems presents information and properties on ten high-temperature tapes. Booklet analyzes each tape individually as to construction and recommends uses. The Conn. Hard Rubber Co., New Haven, Conn.

⅞" Pot and Dial 486

Scaled-down, "economy model" precision potentiometer and turns-counting dial provide the subject matter for two new data sheets. A 10-turn bushing mount potentiometer measuring ⅞" in diameter is said to be ideally suited for trim application. Resistance range is 10 to 125,000 ohms and standard linearity tolerance is ±0.50%. Helipot Technical Information Service, Fullerton, Calif.

Impulse Counters 487

Described in a bulletin are electric and manual reset counters, monodecade and predetermining counters, time indicators, printing counters, heavy duty counters and impulse transmiers. Landis & Gyr, Inc., New York, N.Y.

Angular Displacement Transmitter 488

High output transducer translates angular position or displacement into voltage suitable for operating meters, recorders or servo controls. The electrical sensing element is a specially designed differential transformer. No external electrical balancing arms are required. The shaft makes no electrical or mechanical contact with the sensing coils. Dynamic Msmts Co., Jenkintown, Pa.

Fast Pulse Camera 489

16MM pulse camera can be pulsed to 30 fps and carries 100 feet of film. Literature describes an important application in destructive resonances in vibration tests where camera teams with auxiliary stroboscopic equipment to make movies of events as fast as 10,000 cps. Camera is directly useful for conventional pulse camera data recordings and for time-lapse work. Chadwick-Helmuth Co., Monrovia, Calif.

Tantalum Capacitors 490

Detailing engineering information on solid tantalum capacitors, a 4 page catalog provides engineering curves and reference tables. Units are available in a wide range of capacitance and voltage combinations. Aerovox Corp., New Bedford, Mass.

Semiconductor Test Equipment 491

Brochure describes automatic test and classification equipment for semiconductor devices. Units test parameters of all types of transistors at rates varying from 750 per hour to 3600 per hour. Industro Transistor Corp., Long Island City, N.Y.

Epoxy Resins 492

The Emerson & Cuming standard resins chart has been brought up to date to function as a reference for information about epoxy and ceramic type casting and impregnating resins and adhesives. Some of the new products presented are: Eccoceram QC, a quartz embedment compound for 3000 F use; Stycast TPM-4, a Class A, Mil I-16923 C type resin; Eccobond 70C, a low cost, completely conductive epoxy adhesive. Emerson & Cuming, Inc., Canton, Mass.

Chart Drives 475

Catalog on multi-speed chart drives includes table showing all eight chart speeds provided by each model and instructions for ordering proper model for any standard recorder. Text describes advantages of quick, easy chart speed change replacing gears, potential savings in chart paper costs and ability to match chart speed to test requirements with improved resolution and readability. Insco Co., Div. Barry Controls, Groton, Mass.

Control Knobs 476

Mil-spec control knobs made of plastic, type III, class H2, per specification L-P-349, are available in five sizes, six styles, three shaft diameters and three finishes. National Radio Co., Inc., New York, N.Y.

Potentiometers 477

Combining high temperature operation with long load life, precision potentiometers have been laboratory and field tested for nearly two years. Units are manufactured with 20 ppm resistance wire and can dissipate 2 watts at 125 C for more than 2,000 hours. All models contain a drum design which permits conformities to 0.1% for all resistance values and up to 16 taps to ±0.25°. Carter Mfg. Corp., Hudson, Mass.

Ceramic Memory Devices 478

The application of electronic ceramics in multi-aperture devices, read selector module assemblies, shift registers, logic module assemblies, memory cores and planes and recording heads is discussed in an 8 page brochure. Lockheed Electronics Co., Los Angeles, Calif.

Power Supplies 479

Bulletin presents performance characteristics in tabular form for a complete line of power supplies. Units with advanced circuit techniques reduce transients to a minimum. Models include transistorized and vacuum tube, rack and modular design. Anders Electric Products Inc., Needham Hts., Mass.

Power Cables 480

High voltage power cables are designed for installation in conduits, underground ducts, open air or direct burial. Throughout the entire length of each cable, there is a high degree of uniformity in density, wall thickness, concentricity and freedom from flattening and internal blistering. Electrolytic or chemical corrosion of lead sheath is eliminated by use of non-metallic jacket. Copper operating temperature is 90 C for cables rated 5kv and 85 C for cables rated above 5kv. Crescent Ins. Wire & Cable Co., Trenton, N.J.

Transformers 483

Brochure on transformers for transistor power supplies provides specs including resistance and capacitance values for all circuits. Wiring diagrams and schematics, as well as lists of typical transistors and rectifiers for each transformer are included. Complete transistor transformer line consists of 23 units for dc to dc conversion and 3 units for dc to ac conversion. Triad Transformer Corp., Venice, Calif.

Enameled Wire 484

Properties of enameled wire magnet wire and thin wall instrument wire are described in an 8 page catalog. Special constructions, packaging and complete specification are given. Tensolite Insulated Wire Co., Inc., Peekskill, N.Y.

Silver Alloy Brazing 599

Bulletin describes advantages of a silver alloy brazing technique. The bulletin states that with the use of this technique, designers can combine copper, brass and bronze in any combination; design for castings, sheet metal, forgings, screw machine products and stamping in any arrangement. Handy & Harman, New York, N.Y.

Contact Assemblies 598

How to re-design staked, brazed or welded electrical contact assemblies to permit simplified manufacture, increased strength and accurate dimensional control by means of top-lay contacts or clad strip material is described in a four page brochure. Listed are some of the types and properties of precious and base metals that can be combined in top-lay strip as bimetal or trimetal. Also, a series of diagrams compares design configurations of conventional staked, brazed or welded assemblies with alternates manufactured by the top-lay method. Texas Instruments Inc., Attleboro, Mass.

Electric Eyes 597

Six page brochure covers developments in design and application of electric eyes. Included is an interesting comparison between the human eye and the photo electric eye. Booklet also contains the method of operation of various types of other measuring units, ranging from smoke indicators to recorders and electronic controls. Photomation, Inc., Bergenfield, N.J.

Core Tester 424

Designed for production-line testing of ferrite magnetic memory cores, this unit permits high-speed automatic testing of cores to all common quality control specifications. Folder on core tester contains block diagram of sensing and decision circuitry, four different programs of current driving pulses and examples of test accept and reject criteria. Digital Equipment Corp., Maynard, Mass.

Frequency Discriminator 481

Engineering data sheet on a 115-volt, 400-cycle, 0-5 volt dc range frequency discriminator, contains a general description of operation and applications. A signal frequency graph is also included. Magnetic Research Corp., Hawthorne, Calif.

Legend Light 482

Flush mounting legend light for airborne or ground support applications installs completely flush with panel and may be re-lamped without special tools. Available individually or in stacked and tandem assemblies. Radar Relay, Inc., Santa Monica, Calif.

Metalized Ceramic Housings 377

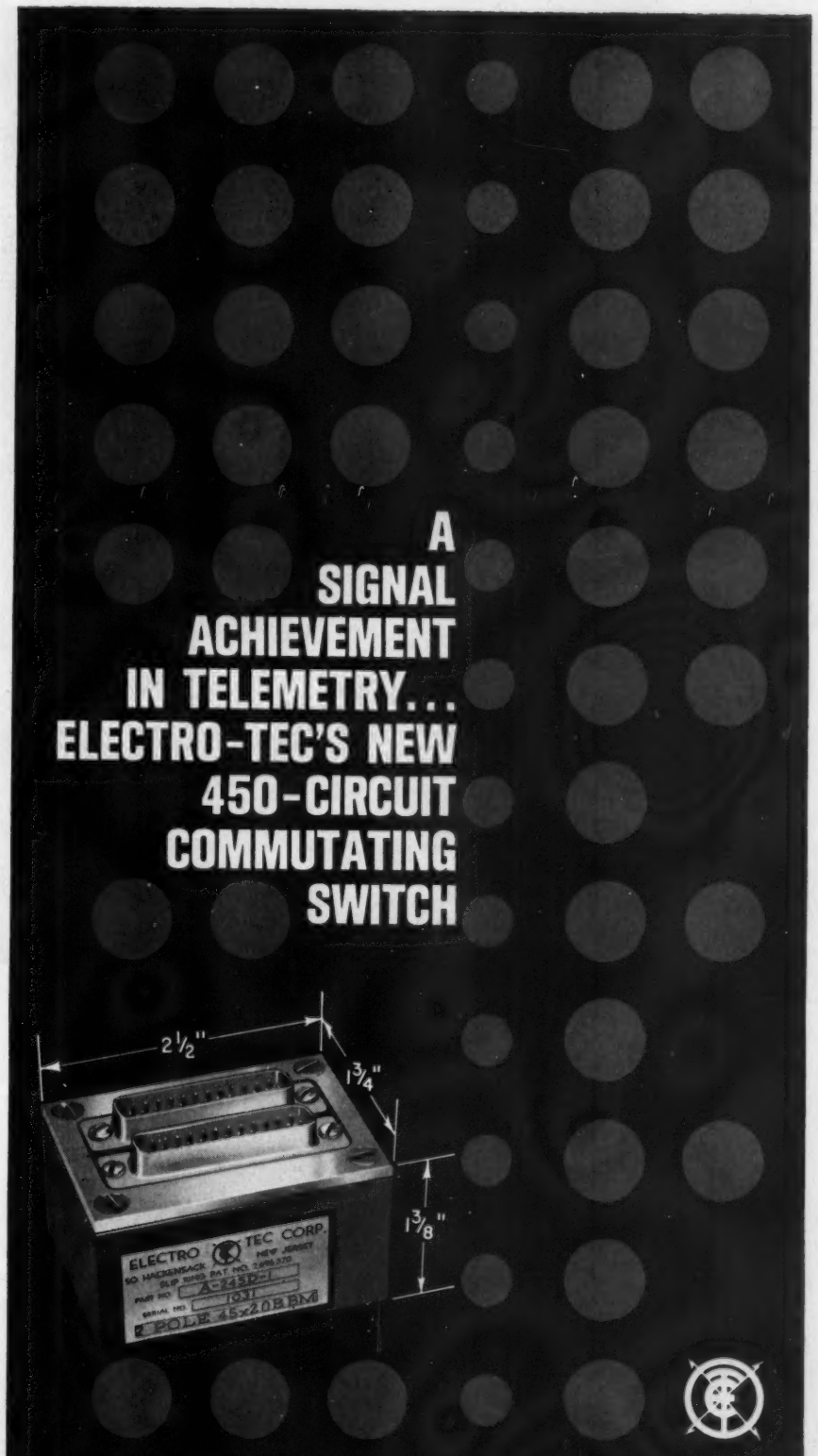
Offering complete specifications on metalized ceramic resistor housings, bulletin lists the various advantages of this method of encapsulating resistors. Various grades of ceramic in which the housings are available include L3, L4 and L5 steatites and 75 and 85 percent alumina ceramics. Metalizing Industries, Inc., Hackensack, N.J.

Transistorized Power Supplies 376

Information in 4-page bulletin on transistorized power supplies includes complete specifications, mounting dimensions, special features and prices for 19 off-the-shelf units. Trouble-shooting data, including individual schematics and step-by-step adjustment procedures, is furnished separately with each supply. Mid-eastern Electronics, Inc., Springfield, N.J.

WWV Receivers 375

Designed especially for calibration of field research gear and remote location work under extreme environmental conditions in the geophysical, communications and general electronics field, these transistorized receiver features small size, low weight and portability. The instrument is also available for rack mounting. Specific Products, Woodland Hills, Cal.



Electro-Tec's new compact 8-oz. motor driven telemetering switch enables circuit combinations up to a maximum of 5 poles, 90 channels per pole . . . truly the answer to precision performance with optimum size and weight.

Specifically developed for satellite and missile use, the ETC switch incorporates unique engineering ideas extending its utility to a variety of other military and industrial applications. Exclusive microminiature design minimizes brush velocity. Precious metal contact surfaces assure lowest levels of noise and resistance. Hermetically-sealed connectors add to environmental protection. These and other features provide a life expectancy of well beyond 1000 hours.

Write for new ETC switch brochure.

ELECTRO-TEC CORP. Administrative and Executive Offices: 10 Romanelli Avenue, South Hackensack, N.J. Manufacturing Plants: Blacksburg, Va.—Ormond Beach, Fla.

PATENT NUMBER 2,696,570 AND OTHERS PENDING.

CIRCLE NO. 37 ON INQUIRY CARD

Pressure switches that only turn on warning lights in uncontaminated air find it tough going in such a simple thing as salt air atmospheres.

The way you beat this problem is to check the pressure switch under every known operating requirement . . . not just in a vacuum, or 0% humidity or just at sea level, for instance.

Take Model 6621 shown at right that can do so many jobs . . . operate warning lights, measure fuel and oil pressures, actuate air-conditioning for electronic gear. This model, in ranges from 5 to 1000 psig, operates between −65 to 275°F, withstands shock up to 100 g's and vibration to 2000 cps. It is only 1 1/16" diameter by 2½" and weighs but two ounces.

Copy us. Test it yourself for six weeks under all the requirements of your job.

Or save six weeks by checking our own test data on a full line of pressure switches for the type that meets your needs best. Call Mr. Charles Colt at Consolidated Controls, Bethel, Conn. Phone Pioneer 3-6721, DDD Code 203.

Inches of Water to Hundreds of Atmospheres

Model 6621 shown above is one of more than 300 pressure switches available from Consolidated Controls for missile, aircraft and nuclear applications. Working pressures range from 10" of water to 10,000 psi at ambient temperatures from −65°F to 1000°F. Standard models for

- high vibration
- differential pressures
- hydraulic
- miniaturized applications
- high temperature

CONSOLIDATED CONTROLS CORPORATION

A Member of The Condec Group

BETHEL, CONNECTICUT
INGLEWOOD, CALIFORNIA

CIRCLE NO. 67 ON INQUIRY CARD

Solid State Devices 566

Four page brochure describes magnetic circuit and solid state devices including magnetic amplifiers and power supplies. Typical mag. amp. is a 3 watt model measuring 1 3/16 sq. in. by 2 inches in height. Units are compatible with either silicon or germanium transistor device circuits, exhibit a 12 millisec response and are said to withstand high line transients without damage. Meet Mil-T-27, Mil-E-5400 and Mil-E-189. Pennon Electronics, Inc., Bell Gardens, Calif.

Connectors 567

Miniature rectangular connectors contain crimp termination removable contacts. Extra-wide, three-tine spring clutch on pin and socket provides maximum holding area between contact and molded block. All sharp-edged, "molded-in" metal inserts have been eliminated. Socket and pin contact material is phosphor bronze, gold plate over silver plate. 6 page brochure provides detail information. Continental Connector Corp., Woodside, N.Y.

Force Control Switches 568

Bulletin describes force control switches which operate in compression or tension and which can trigger as many as four separate operations. The devices start and stop motors and relays, sound audible warnings or activate visual signals. Any one of six basic capacities may be set for a specific load point or points. Sub-miniature models operate in the same manner as higher capacities covering ranges of 0-5, 0-30 and 0-100 pounds. W. C. Dillon & Co., Van Nuys, Calif.

Control Switches 569

Catalog covers break-glass switches, control stations for mechanically held switches and relays, relay panel for gas valve, engine generator isolating switches, marine duty transfer switches and phase sequence correctors. Automatic Switch Co., Florham Park, N.J.

Vacuum Pumps 570

Vacuum pumping systems for a variety of applications are described in 14 page brochure. Type PSM-110, a tenport manifold vacuum system, is designed for processing relays, transistors, and similar small electronic components. Standard accessories adapt this unit for use in leak detection and increase its versatility in a number of other ways. Consolidated Vacuum Corp., Rochester, N.Y.

Fiber Glass Plastics 446

Materials for fibrous glass reinforced plastics including complete ranges of fiber glass fabrics and fibers, polyester and epoxy resins and catalysts, parting agents, pigments and other necessary supplies, along with thumbnail descriptions of properties, tables and recommended applications are contained in catalog. Cadillac Plastic & Chemical Co., Detroit 3, Mich.

Electronic Temperature Controllers 545

Four-page brochure describes a portable temperature controller incorporating the thermistor as the temperature sensing element and combining the three major modes of indicating control; on-off, proportional control and adjustable differential, all at the flip of a switch. Unit covers the range of −100 to 600 F. Fenwal Inc., Ashland, Mass.

2½" Panel Instruments 546

Available as microammeters, milliameters, ammeters and voltmeters in a variety of ranges, panel instruments with an expanded scale plate provide good readability and high reliability. A self-shielding internal core magnet with high torque eliminates the need for special calibrations when mounting on magnetic or non-magnetic panels. All models have an external zero adjuster. DeJur-Amsco Corp., Long Island City, N.Y.

R.E. CARROLL, DIR.
ENG. COLLEGE INDUST. PGRM
UNIV. OF MICH.